OCR
Oxford Cambridge and RSA

Wednesday 12 June 2019 – Morning

A Level Mathematics A

H240/02 Pure Mathematics and Statistics

Time allowed: 2 hours

You must have:
- Printed Answer Booklet

You may use:
- a scientific or graphical calculator

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INSTRUCTIONS
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Answer **all** the questions.
- **Write your answer to each question in the space provided in the Printed Answer Booklet.** If additional space is required, you should use the lined page(s) at the end of the Printed Answer Booklet. The question number(s) must be clearly shown.
- You are permitted to use a scientific or graphical calculator in this paper.
- Give non-exact numerical answers correct to 3 significant figures unless a different degree of accuracy is specified in the question.
- The acceleration due to gravity is denoted by $g\,\mathrm{m\,s^{-2}}$. Unless otherwise instructed, when a numerical value is needed, use $g = 9.8$.

INFORMATION
- The total mark for this paper is **100**.
- The marks for each question are shown in brackets **[ ]**.
- **You are reminded of the need for clear presentation in your answers.**
- The Printed Answer Booklet consists of **16** pages. The Question Paper consists of **12** pages.

Formulae
A Level Mathematics A (H240)

Arithmetic series

$S_n = \frac{1}{2}n(a+l) = \frac{1}{2}n\{2a+(n-1)d\}$

Geometric series

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

$$S_\infty = \frac{a}{1-r} \quad \text{for } |r| < 1$$

Binomial series

$$(a+b)^n = a^n + {}^nC_1 a^{n-1}b + {}^nC_2 a^{n-2}b^2 + \ldots + {}^nC_r a^{n-r}b^r + \ldots + b^n \qquad (n \in \mathbb{N}),$$

where ${}^nC_r = {}_nC_r = \binom{n}{r} = \frac{n!}{r!(n-r)!}$

$$(1+x)^n = 1 + nx + \frac{n(n-1)}{2!}x^2 + \ldots + \frac{n(n-1)\ldots(n-r+1)}{r!}x^r + \ldots \qquad (|x| < 1, n \in \mathbb{R})$$

Differentiation

$\mathrm{f}(x)$	$\mathrm{f}'(x)$
$\tan kx$	$k\sec^2 kx$
$\sec x$	$\sec x \tan x$
$\cot x$	$-\mathrm{cosec}^2 x$
$\mathrm{cosec}\, x$	$-\mathrm{cosec}\, x \cot x$

Quotient rule $y = \frac{u}{v}$, $\frac{\mathrm{d}y}{\mathrm{d}x} = \frac{v\frac{\mathrm{d}u}{\mathrm{d}x} - u\frac{\mathrm{d}v}{\mathrm{d}x}}{v^2}$

Differentiation from first principles

$$\mathrm{f}'(x) = \lim_{h \to 0} \frac{\mathrm{f}(x+h) - \mathrm{f}(x)}{h}$$

Integration

$$\int \frac{\mathrm{f}'(x)}{\mathrm{f}(x)}\,\mathrm{d}x = \ln|\mathrm{f}(x)| + c$$

$$\int \mathrm{f}'(x)(\mathrm{f}(x))^n\,\mathrm{d}x = \frac{1}{n+1}(\mathrm{f}(x))^{n+1} + c$$

Integration by parts $\int u\frac{\mathrm{d}v}{\mathrm{d}x}\,\mathrm{d}x = uv - \int v\frac{\mathrm{d}u}{\mathrm{d}x}\,\mathrm{d}x$

Small angle approximations

$\sin\theta \approx \theta$, $\cos\theta \approx 1 - \frac{1}{2}\theta^2$, $\tan\theta \approx \theta$ where θ is measured in radians

Trigonometric identities

$\sin(A \pm B) = \sin A \cos B \pm \cos A \sin B$

$\cos(A \pm B) = \cos A \cos B \mp \sin A \sin B$

$\tan(A \pm B) = \dfrac{\tan A \pm \tan B}{1 \mp \tan A \tan B} \qquad \left(A \pm B \neq (k+\tfrac{1}{2})\pi\right)$

Numerical methods

Trapezium rule: $\int_a^b y\,\mathrm{d}x \approx \frac{1}{2}h\{(y_0 + y_n) + 2(y_1 + y_2 + \ldots + y_{n-1})\}$, where $h = \dfrac{b-a}{n}$

The Newton-Raphson iteration for solving $\mathrm{f}(x) = 0$: $x_{n+1} = x_n - \dfrac{\mathrm{f}(x_n)}{\mathrm{f}'(x_n)}$

Probability

$\mathrm{P}(A \cup B) = \mathrm{P}(A) + \mathrm{P}(B) - \mathrm{P}(A \cap B)$

$\mathrm{P}(A \cap B) = \mathrm{P}(A)\mathrm{P}(B \mid A) = \mathrm{P}(B)\mathrm{P}(A \mid B)$ **or** $\mathrm{P}(A \mid B) = \dfrac{\mathrm{P}(A \cap B)}{\mathrm{P}(B)}$

Standard deviation

$\sqrt{\dfrac{\Sigma(x-\overline{x})^2}{n}} = \sqrt{\dfrac{\Sigma x^2}{n} - \overline{x}^2}$ **or** $\sqrt{\dfrac{\Sigma f(x-\overline{x})^2}{\Sigma f}} = \sqrt{\dfrac{\Sigma fx^2}{\Sigma f} - \overline{x}^2}$

The binomial distribution

If $X \sim B(n, p)$ then $P(X = x) = \dbinom{n}{x} p^x (1-p)^{n-x}$, mean of X is np, variance of X is $np(1-p)$

Hypothesis test for the mean of a normal distribution

If $X \sim \mathrm{N}(\mu, \sigma^2)$ then $\overline{X} \sim \mathrm{N}\left(\mu, \dfrac{\sigma^2}{n}\right)$ and $\dfrac{\overline{X} - \mu}{\sigma / \sqrt{n}} \sim \mathrm{N}(0, 1)$

Percentage points of the normal distribution

If Z has a normal distribution with mean 0 and variance 1 then, for each value of p, the table gives the value of z such that $P(Z \leqslant z) = p$.

p	0.75	0.90	0.95	0.975	0.99	0.995	0.9975	0.999	0.9995
z	0.674	1.282	1.645	1.960	2.326	2.576	2.807	3.090	3.291

Kinematics

Motion in a straight line

$v = u + at$

$s = ut + \frac{1}{2}at^2$

$s = \frac{1}{2}(u + v)t$

$v^2 = u^2 + 2as$

$s = vt - \frac{1}{2}at^2$

Motion in two dimensions

$\mathbf{v} = \mathbf{u} + \mathbf{a}t$

$\mathbf{s} = \mathbf{u}t + \frac{1}{2}\mathbf{a}t^2$

$\mathbf{s} = \frac{1}{2}(\mathbf{u} + \mathbf{v})t$

$\mathbf{s} = \mathbf{v}t - \frac{1}{2}\mathbf{a}t^2$

Section A: Pure Mathematics

Answer **all** the questions.

1 **(a)** Differentiate the following.

(i) $\dfrac{x^2}{2x+1}$ **[3]**

(ii) $\tan(x^2 - 3x)$ **[2]**

(b) Use the substitution $u = \sqrt{x} - 1$ to integrate $\dfrac{1}{\sqrt{x}-1}$. **[4]**

(c) Integrate $\dfrac{x-2}{2x^2-8x-1}$. **[2]**

ai Use the quotient rule

$\left(\frac{d}{dx}\left(\frac{v}{u}\right) = \frac{uv' - u'v}{u^2}\right)$

$v = x^2 \quad v' = 2x$

$u = 2x+1 \quad u' = 2$

$$\frac{uv' - vu'}{u^2} = \frac{2x(2x+1) - 2x^2}{(2x+1)^2}$$

$$= \frac{4x^2 + 2x - 2x^2}{(2x+1)^2}$$

$$= \frac{2x^2 + 2x}{(2x+1)^2}$$

$$= \frac{2x(x+1)}{(2x+1)^2}$$

ii) $\tan(x^2 - 3x)$

Let $x^2 - 3x = u$ $\quad \therefore y = \tan u$

$$\frac{dy}{du} = \sec^2 u \qquad \frac{du}{dx} = 2x - 3$$

$$\therefore \frac{dy}{dx} = \frac{dy}{\cancel{du}} \times \frac{\cancel{du}}{dx} = \sec^2 u \times 2x - 3 \Rightarrow (2x-3)\sec^2(x^2-3x)$$

b) let $u = \sqrt{x} - 1$ $\quad \int \frac{1}{\sqrt{x}-1}\,dx = ?$

$u = x^{1/2} - 1$

$\Rightarrow \int \frac{1}{u}\,dx \qquad \frac{du}{dx} = \frac{1}{2}x^{-1/2} \qquad \therefore\ dx = \frac{2\,du}{x^{-1/2}}$

$\Rightarrow \int \frac{1}{u} \times \frac{2\,du}{x^{-1/2}}$ $\qquad$ From $u = x^{1/2} - 1$

$\Rightarrow (u+1)^2 = x$

$\therefore \int \frac{1}{u} \times \frac{2\,du}{[(u+1)^{\cancel{2}}]^{-1/\cancel{2}}} \Rightarrow \int \frac{1}{u} \times \frac{2\,du}{(u+1)^{-1}}$

$\Rightarrow 2\int \frac{1}{u(u+1)^{-1}}\,du \Rightarrow 2\int \frac{u+1}{u}\,du$

$\Rightarrow 2\int\left(\frac{u}{u} + \frac{1}{u}\right)du \Rightarrow 2\int\left(1 + \frac{1}{u}\right)du$

$\Rightarrow 2\left[u + \ln|u|\right]$ $\qquad$ BUT $u = x^{1/2} - 1$

$\therefore 2\left[x^{1/2} - 1 + \ln|x^{1/2} - 1|\right]$

$\Rightarrow 2\left[\sqrt{x} - 1 + \ln|\sqrt{x} - 1|\right]$

c) $\displaystyle\int \frac{x-2}{2x^2-8x-1}\,dx.$

Using reverse chain rule;

let $u = 2x^2-8x-1$

$\frac{du}{dx} = 4x-8.$

$dx = \frac{du}{4(x-2)}$

$\therefore \displaystyle\int \frac{\cancel{x-2}}{u} \times \frac{du}{4\cancel{(x-2)}} \Rightarrow \int \frac{1}{4u}\,du \Rightarrow \frac{1}{4}\ln|u| + C$

But $u = 2x^2-8x-1$

$\therefore \Rightarrow \boxed{\frac{1}{4}|2x^2-8x-1| + C}$

2 **(a)** Find the coefficient of x^5 in the expansion of $(3-2x)^8$. **[1]**

(b) **(i)** Expand $(1+3x)^{0.5}$ as far as the term in x^3. **[3]**

(ii) State the range of values of x for which your expansion is valid. **[1]**

A student suggests the following check to determine whether the expansion obtained in part **(b)(i)** may be correct.

"Use the expansion to find an estimate for $\sqrt{103}$, correct to five decimal places, and compare this with the value of $\sqrt{103}$ given by your calculator."

(iii) Showing your working, carry out this check on your expansion from part **(b)(i)**. **[3]**

a) $(3-2x)^8$

$\binom{8}{3}(3)^3(-2x)^5 \Rightarrow 56 \times 27 \times -32x^5$

$= -48384x^5$

$\therefore$ co-efficient $= -48384$

bi) $(1+3x)^{1/2}$

$$1 + \frac{\left(\frac{1}{2}\right) \times (3x)^1}{1!} + \frac{\left(\frac{1}{2}\right)\left(-\frac{1}{2}\right)(3x)^2}{2!} + \frac{\left(\frac{1}{2}\right)\left(-\frac{1}{2}\right)\left(-\frac{3}{2}\right)(3x)^3}{3!}$$

$\Rightarrow 1 + \frac{3x}{2} - \frac{9}{8}x^2 + \frac{27}{16}x^3 \ldots$

ii) $-\frac{1}{3} < x < \frac{1}{3}$

iii) What will we substitute for our value of x? given

$-\frac{1}{3} < x < \frac{1}{3}$

$\frac{103}{100} = 1.03$ $\quad \therefore \sqrt{\frac{103}{100}} = \frac{\sqrt{103}}{10}$

$\therefore 1.03 = 3x + 1$

$1.03 - 1 = 3x \quad \underbrace{x = 0.01}$

this is your substitution for x.

$x = 0.01$

$1 + \frac{3}{2}(0.01) - \frac{9}{8}(0.01)^2 + \frac{27}{16}(0.01)^3$

$= 1.041889188 \times 10$

$= 10.41889188$

From calculator

$\sqrt{103} = 10.14889157$

$\Rightarrow$ It is correct to 6dp $\therefore$ expansion may be correct.

3 (a) A circle is defined by the parametric equations $x = 3 + 2\cos\theta$, $y = -4 + 2\sin\theta$.

(i) Find a cartesian equation of the circle. **[2]**

(ii) Write down the centre and radius of the circle. **[1]**

(b) **In this question you must show detailed reasoning.**

The curve S is defined by the parametric equations $x = 4\cos t$, $y = 2\sin t$. The line L is a tangent to S at the point given by $t = \frac{1}{6}\pi$.

Find where the line L cuts the x-axis. **[6]**

a) $x = 3 + 2\cos\theta$

$x - 3 = 2\cos\theta$

$x-3/2 = \cos\theta$

$y = -4 + 2\sin\theta$

$y + 4 = 2\sin\theta$

$\frac{y+4}{2} = \sin\theta$

$\cos^2\theta + \sin^2\theta = 1$

$$\left[\frac{(x-3)}{2}\right]^2 + \left[\frac{(y+4)}{2}\right]^2 = 1$$

$$\Rightarrow \frac{(x-3)^2}{4} + \frac{(y+4)^2}{4} = 1 \Rightarrow (x-3)^2 + (y+4)^2 = 4$$

ii) $(x-a)^2 + (y-b)^2 = r^2$

centre $= (a, b)$

radius $= r$

$\therefore$ centre : $(3, -4)$

radius : 2

b) $x = 4\cos t$

$\frac{dx}{dt} = -4\sin t$

$y = 2\sin t$

$\frac{dy}{dt} = 2\cos t$

$$\frac{dy}{dx} = \frac{dy}{dt} \times \frac{dt}{dx}$$

$$= 2\cos t \times \frac{1}{-4\sin t} \qquad = -\frac{\cos t}{2\sin t} \quad @\ t = \frac{\pi}{6}$$

$$\Rightarrow \frac{-\cos(\pi/6)}{2\sin(\pi/6)} = -\frac{\sqrt{3}}{2} \rightarrow \text{gradient.}$$

$$y - y_0 = m(x - x_0)$$

$$y - 2\sin(\pi/6) = -\frac{\sqrt{3}}{2}(x - 4\cos(\pi/6))$$

$$\Rightarrow y - 1 = -\frac{\sqrt{3}}{2}(x - 2\sqrt{3})$$

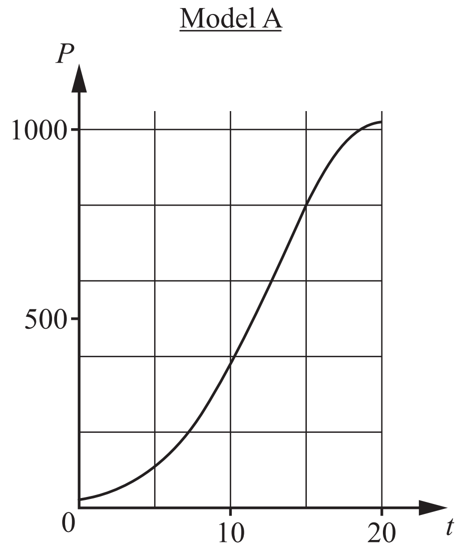
X int $y=0$

$$0 - 1 = -\frac{\sqrt{3}}{2}(x - 2\sqrt{3})$$

$$-\frac{2}{\sqrt{3}} = -x + 2\sqrt{3} \qquad x = \frac{8\sqrt{3}}{3}$$

$$\therefore \text{X int} = \left(\frac{8\sqrt{3}}{3}, 0\right)$$

4 A species of animal is to be introduced onto a remote island. Their food will consist only of various plants that grow on the island. A zoologist proposes two possible models for estimating the population P after t years. The diagrams show these models as they apply to the first 20 years.



(a) Without calculation, describe briefly how the rate of growth of P will vary for the first 20 years, according to each of these two models. **[1]**

The equation of the curve for model A is $P = 20 + 1000\mathrm{e}^{-\frac{(t-20)^2}{100}}$.

The equation of the curve for model B is $P = 20 + 1000\left(1 - \mathrm{e}^{-\frac{t}{5}}\right)$.

(b) Describe the behaviour of P that is predicted for $t > 20$

(i) using model A, **[1]**

(ii) using model B. **[1]**

There is only a limited amount of food available on the island, and the zoologist assumes that the size of the population depends on the amount of food available and on no other external factors.

(c) State what is suggested about the long-term food supply by

(i) model A, **[1]**

(ii) model B. **[1]**

a) A: Growth rate increases then decreases

B: Growth rate decreases.

bi) A: $e^{-\frac{\infty}{100}} = 0$

$1000(0) = 0$ $\therefore 20 + 0 = 20$

$\therefore$ tends to 20 for $t > 20$

ii) B: $e^{-\infty/5} \Rightarrow 0$

$(1-0) = 1$

$1000(1) = 1000$

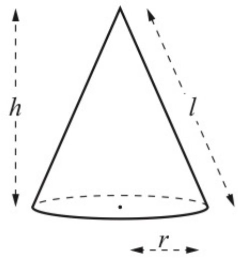
$1000 + 20 = 1020$

$\therefore$ tends to 1020 for $t > 20$

ci) A: Food runs out

ii) B: Food is sufficient to support a population that ≈ 1020.

5



For a cone with base radius r, height h and slant height l, the following formulae are given.

Curved surface area, $S = \pi r l$

Volume, $V = \frac{1}{3}\pi r^2 h$

A container is to be designed in the shape of an inverted cone with no lid. The base radius is r m and the volume is V m^3.

The area of the material to be used for the cone is 4π m^2.

(a) Show that $V = \frac{1}{3}\pi\sqrt{16r^2 - r^6}$. **[4]**

(b) **In this question you must show detailed reasoning.**

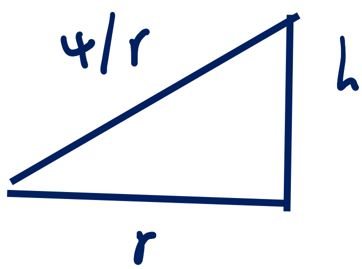
It is given that V has a maximum value for a certain value of r.

Find the maximum value of V, giving your answer correct to 3 significant figures. **[5]**

a) $4\cancel{\pi} = \cancel{\pi} r l$

$l = \frac{4}{r}$

$V = \frac{1}{3}\pi r^2 h$



From this diagram

$h = \sqrt{(4/r)^2 - (r)^2}$

$$h = \sqrt{16/r^2 - r^2} = \sqrt{\frac{16 - r^4}{r^2}} = \frac{\sqrt{16 - r^4}}{r}$$

$$\therefore \; V = \frac{1}{3}\pi \cancel{r^2}^{\,r} \times \frac{\sqrt{16 - r^4}}{\cancel{r}}$$

$$\Rightarrow \; V = \frac{1}{3}\pi r \sqrt{16 - r^4}$$

$$= \frac{1}{3}\pi \sqrt{r^2(16 - r^4)}$$

$$= \frac{1}{3}\pi \sqrt{16r^2 - r^6} \quad \text{as required.}$$

b) $\frac{dV}{dr} = ?$

$$V = \frac{1}{3}\pi (16r^2 - r^6)^{1/2}$$

let $16r^2 - r^6 = u$

$$\frac{du}{dr} = 32r - 6r^5$$

<u>Using chain rule</u>

$$\frac{dV}{du} = \frac{1}{3}\pi \times \frac{1}{2}(u)^{-1/2}$$

$$\frac{dV}{dr} = \frac{dV}{\cancel{du}} \times \frac{\cancel{du}}{dr}$$

$$= \frac{1}{3}\pi \times \frac{1}{2}\left(16r^2 - r^6\right)^{-1/2} \times \left(32r - 6r^5\right)$$

$$\frac{dV}{dr} = \frac{\pi\left(32r - 6r^5\right)}{6\left(16r^2 - r^6\right)^{1/2}}$$

Max value occurs at $\frac{dV}{dr} = 0$

$$\pi\left(32r - 6r^5\right) = 0$$

$$32r - 6r^5 = 0$$

$$r\left(32 - 6r^4\right) = 0$$

$$6r^4 = 32$$

$$r^4 = \frac{16}{3}$$

$$r = \pm\sqrt[4]{16/3}$$

Radius is scalar $\therefore$ $r > 0$

$$\therefore r = +\sqrt[4]{16/3}$$

$\therefore$ <u>Max value of V</u>;

$$V = \frac{1}{3}\pi\sqrt{16\left(\sqrt[4]{16/3}\right)^2 - \left(\sqrt[4]{16/3}\right)^6}$$

$V = 5.20$ (3sf)

6 Shona makes the following claim.

"n is an **even** positive integer greater than $2 \Rightarrow 2^n - 1$ is **not** prime"

Prove that Shona's claim is true. **[4]**

An even number is represented by $n = 2k$. where k is an integer & $k > 1$

$\therefore 2^{2k} - 1$

$\Rightarrow \underbrace{(2^k)^2 - 1}$

difference between 2 squares

$\Rightarrow (2^k - 1)(2^k + 1)$

$(2^k + 1) > 1$ and $k > 1$, hence $(2^k - 1) > 1$

$\therefore (2^k + 1)(2^k - 1)$ is a product of 2 integers both greater than 1, hence $2^n - 1$ is not prime. $\therefore$ Shona's claim is true.

7 In this question you must show detailed reasoning.

Use the substitution $u = 6x^2 + x$ to solve the equation $36x^4 + 12x^3 + 7x^2 + x - 2 = 0$. **[5]**

$u = 6x^2 + x \quad \therefore \quad u^2 = (6x^2 + x)^2$

$\Rightarrow u^2 = 36x^4 + 12x^3 + x^2$

$\therefore$ The equation: $u^2 + u - 2 = 0$

$(u+2)(u-1) = 0$

$u = -2 \quad u = 1$

$\underline{u = -2}$

$\therefore 6x^2 + x = -2$

$6x^2 + x + 2 = 0$

no real roots as

$b^2 - 4ac < 0$

$\underline{u = 1}$

$6x^2 + x = 1$

$6x^2 + x - 1 = 0$

$(3x-1)(2x+1) = 0$

$x = 1/3 \quad x = -1/2$

Section B: Statistics

Answer **all** the questions.

8 The stem-and-leaf diagram shows the heights, in centimetres, of 17 plants, measured correct to the nearest centimetre.

5	5 7 9 9
6	3 4 5 5 5 9 9
7	4 5 7 9 9
8	
9	9

Key: 5 | 6 means 56

(a) Find the median and inter-quartile range of these heights. **[3]**

(b) Calculate the mean and standard deviation of these heights. **[2]**

(c) State one advantage of using the median rather than the mean as a measure of average for these heights. **[1]**

a) Median

5	5 7 9 9
6	3 4 5 5 5 9 9
7	4 5 7 9 9
8	
9	9

Key: 5 | 6 means 56

$\therefore$ Median = 65.

Lower quartile.

$\frac{1}{4} \times 17 = 4.25$

$\therefore$ Between 4 & 5 $= \frac{59+63}{2} = 61$

Upper quartile

$\frac{3}{4} \times 17 = 12.75$

$\therefore$ Between 12 & 13 $= \frac{75+77}{2} = 76$

$\therefore$ IQR $=$ UQ $-$ LQ $= 76 - 61$

$= 15$

b) Mean

$\frac{\sum f(x)}{\sum f} = 55+57+59+59+63+64+65$
$+65+65+69+69+74+75+77+$
$79+79+99 = 1173$

$= \frac{1173}{17} = 69$

S.D

$= \sqrt{\text{variance}}$

Variance

$= \frac{\sum f x^2}{\sum f} - \left(\frac{\sum f(x)}{\sum f}\right)^2$

x	x^2
55	3025
57	3249
59	3481
59	3481
63	3969
64	4096
65	4225
65	4225
65	4225
69	4761
69	4761
74	5476
75	5625
77	5929
79	6241
79	6241
99	9801

$\Sigma = 82811$

$$= \frac{82811}{17} - [69]^2$$

$$= 110.23\ldots$$

$$SD = \sqrt{110.23\ldots}$$

$$= 10.5 \text{ (3sf)}$$

9 **(a)** The masses, in grams, of plums of a certain kind have the distribution N(55, 18).

(i) Find the probability that a plum chosen at random has a mass between 50.0 and 60.0 grams. **[1]**

(ii) The heaviest 5% of plums are classified as extra large.

Find the minimum mass of extra large plums. **[1]**

(iii) The plums are packed in bags, each containing 10 randomly selected plums.

Find the probability that a bag chosen at random has a total mass of less than 530 g. **[4]**

(b) The masses, in grams, of apples of a certain kind have the distribution $N(67, \sigma^2)$. It is given that half of the apples have masses between 62 g and 72 g.

Determine σ. **[5]**

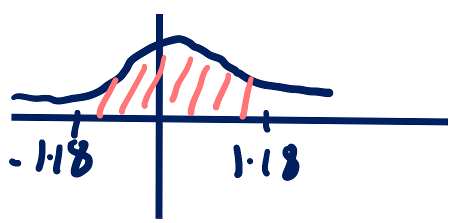
ai) $X \sim N(55, 18)$

$p(50 < X < 60)$

Standardizing it;

$p\left(\frac{50-55}{\sqrt{18}} < Z < \frac{60-55}{\sqrt{18}}\right)$

$p(-1.18 < Z < 1.18)$

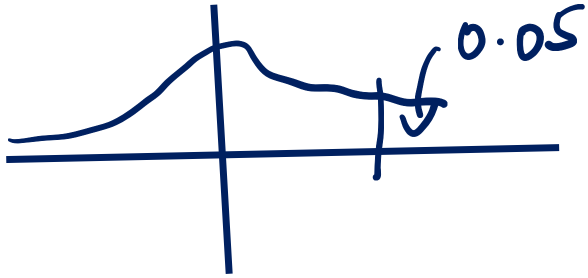


$p(Z < 1.18) - p(Z < -1.18)$

$= 0.881 - (1 - 0.881)$

$= 0.762$

(ii)



$p(X > \alpha) = 0.05$

$p\left(Z > \frac{\alpha - 55}{\sqrt{18}}\right) = 0.05$

$\Rightarrow \frac{\alpha - 55}{\sqrt{18}} = 1.6449.$

$\alpha = 61.97$

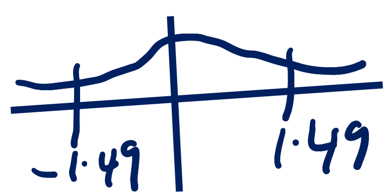
$= 62.0 \ (3sf)$

(iii) $\bar{X} \sim N\left(\mu, \frac{\sigma^2}{n}\right) \Rightarrow \sim\left(55, \frac{18}{10}\right)$

$p\left(\bar{X} < \frac{530}{10}\right)$

$p\left(Z < \frac{53 - 55}{\sqrt{1.8}}\right)$

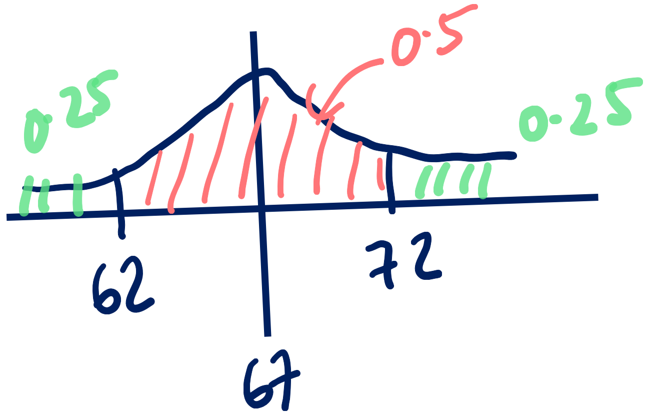
$p(Z < -1.49)$



$\Rightarrow 1 - 0.9319$

$= 0.068$

b)



$P(62 < X < 72) = 0.5$

$P\left(\frac{62-67}{\sigma} < Z < \frac{72-67}{\sigma}\right) = 0.5$

$P(-5/\sigma < Z < 5/\sigma) = 0.5$

From calculator with the aid of the diagram;

$P(Z > 5/\sigma) = 0.75$

$\therefore 5/\sigma = 0.674$

$\sigma = 7.42$ (3sf)

10 The level, in grams per millilitre, of a pollutant at different locations in a certain river is denoted by the random variable X, where X has the distribution $N(\mu, 0.000\,040\,9)$.

In the past the value of μ has been 0.0340.

This year the mean level of the pollutant at 50 randomly chosen locations was found to be 0.0325 grams per millilitre.

Test, at the 5% significance level, whether the mean level of pollutant has changed. **[7]**

10) $X \sim N(\mu, 0.0000409)$

$H_0: \mu = 0.0340$

$H_1: \mu \neq 0.0340$

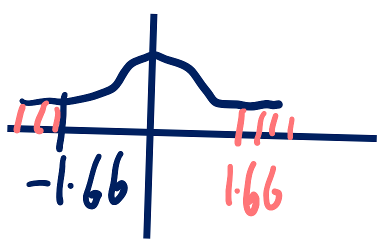
since it is a 2-tailed test, significance level = 2.5%

$\therefore \bar{X} \sim N\left(\mu, \dfrac{0.0000409}{50}\right)$

$P(\bar{X} < 0.0325)$

$$P\left(Z < \frac{0.0325 - 0.0340}{\sqrt{\frac{0.0000409}{50}}}\right)$$

$= P(Z < -1.66)$



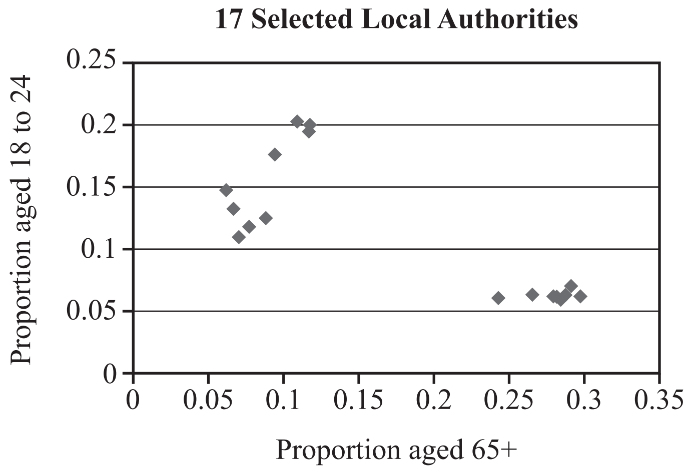
$1 - 0.9515 = 0.0485$

$\therefore \; 0.0485 > 0.025$

$\therefore$ Do not reject H_0.

$\therefore$ Insufficient evidence that pollutant level has changed.

11 A trainer was asked to give a lecture on population profiles in different Local Authorities (LAs) in the UK. Using data from the 2011 census, he created the following scatter diagram for 17 selected LAs.



He selected the 17 LAs using the following method. The proportions of people aged 18 to 24 and aged 65+ in any Local Authority are denoted by P_{young} and P_{senior} respectively. The trainer used a spreadsheet to calculate the value of $k = \dfrac{P_{\text{young}}}{P_{\text{senior}}}$ for each of the 348 LAs in the UK. He then used specific ranges of values of k to select the 17 LAs.

(a) Estimate the ranges of values of k that he used to select these 17 LAs. **[2]**

(b) Using the 17 LAs the trainer carried out a hypothesis test with the following hypotheses.

H_0: There is no linear correlation in the population between P_{young} and P_{senior}.
H_1: There is negative linear correlation in the population between P_{young} and P_{senior}.

He found that the value of Pearson's product-moment correlation coefficient for the 17 LAs is -0.797, correct to 3 significant figures.

(i) Use the table on page 9 to show that this value is significant at the 1% level. **[2]**

The trainer concluded that there is evidence of negative linear correlation between P_{young} and P_{senior} in the population.

(ii) Use the diagram to comment on the reliability of this conclusion. **[2]**

(c) Describe one outstanding feature of the population in the areas represented by the points in the bottom right hand corner of the diagram. **[1]**

(d) The trainer's audience included representatives from several universities.

Suggest a reason why the diagram might be of particular interest to these people. **[1]**

Critical values of Pearson's product-moment correlation coefficient

1-tail test	5%	2.5%	1%	0.5%
2-tail test	10%	5%	2%	1%
n				
1	-	-	-	-
2	-	-	-	-
3	0.9877	0.9969	0.9995	0.9999
4	0.9000	0.9500	0.9800	0.9900
5	0.8054	0.8783	0.9343	0.9587
6	0.7293	0.8114	0.8822	0.9172
7	0.6694	0.7545	0.8329	0.8745
8	0.6215	0.7067	0.7887	0.8343
9	0.5822	0.6664	0.7498	0.7977
10	0.5494	0.6319	0.7155	0.7646
11	0.5214	0.6021	0.6851	0.7348
12	0.4973	0.5760	0.6581	0.7079
13	0.4762	0.5529	0.6339	0.6835
14	0.4575	0.5324	0.6120	0.6614
15	0.4409	0.5140	0.5923	0.6411
16	0.4259	0.4973	0.5742	0.6226
17	0.4124	0.4821	0.5577	0.6055
18	0.4000	0.4683	0.5425	0.5897
19	0.3887	0.4555	0.5285	0.5751
20	0.3783	0.4438	0.5155	0.5614
21	0.3687	0.4329	0.5034	0.5487
22	0.3598	0.4227	0.4921	0.5368
23	0.3515	0.4132	0.4815	0.5256
24	0.3438	0.4044	0.4716	0.5151
25	0.3365	0.3961	0.4622	0.5052
26	0.3297	0.3882	0.4534	0.4958
27	0.3233	0.3809	0.4451	0.4869
28	0.3172	0.3739	0.4372	0.4785
29	0.3115	0.3673	0.4297	0.4705
30	0.3061	0.3610	0.4226	0.4629

a) $k > 1.4$

$k < 0.25$

b)i) $|-0.797| > 0.5577$

ii) → There are clusters of groups

→ This indicates that there is apparently a good correlation caused by clusters.

∴ the conclusion is unreliable.

c) → High proportion of people that are 65+ OR low proportion of people that are between 18–24.

d) Top left points contains a high proportion of people between 18–24.

12 A random variable X has probability distribution defined as follows.

$$P(X=x)=\begin{cases} kx & x=1,2,3,4,5, \\ 0 & \text{otherwise,} \end{cases}$$

where k is a constant.

(a) Show that $P(X=3)=0.2$. **[3]**

(b) Show in a table the values of X and their probabilities. **[2]**

(c) Two independent values of X are chosen, and their total T is found.

(i) Find $P(T=7)$. **[3]**

(ii) Given that $T=7$, determine the probability that one of the values of X is 2. **[4]**

a) $k(1+2+3+4+5)=1$

$$k=\frac{1}{1+2+3+4+5}=\frac{1}{15}$$

$$p(x=3)=3\times\frac{1}{15}=\frac{3}{15}$$

b)

x	1	2	3	4	5
$f(x)$	$\frac{1}{15}$	$\frac{2}{15}$	$\frac{3}{15}$	$\frac{4}{15}$	$\frac{5}{15}$

c i) Probability of T = 7

3, 4
2, 5
4, 3
5, 2

These are the possibilities that T = 7

$$2\left(\frac{3}{15} \times \frac{4}{15}\right) + 2\left(\frac{2}{15} \times \frac{5}{15}\right) = \frac{44}{225}$$

c ii) p(one value is 2 AND T = 7)

$2 \times (2, 5)$

$$= 2 \times \left(\frac{2}{15} \times \frac{5}{15}\right)$$

$$= \frac{4}{45}$$

$$\frac{p(\text{one value is 2 AND } T = 7)}{p(T = 7)}$$

$$= \frac{4/45}{\frac{44}{225}} = \boxed{\frac{5}{11}}$$

13 It is known that 26% of adults in the UK use a certain app. A researcher selects a random sample of 5000 adults in the UK. The random variable X is defined as the number of adults in the sample who use the app.

Given that $P(X < n) < 0.025$, calculate the largest possible value of n. **[5]**

$X \sim B(np, np(1-p))$

$X \sim B(5000 \times 0.26, 5000 \times 0.26 \times (1-0.26))$

$\Rightarrow X \sim B(1300, 962)$

$p(X < n) < 0.025$

$\Rightarrow P(X \leq n-1) < 0.025$

Using the calculator;

inverse Bin $(0.025) = 1239$

$p(X \leq 1239) = 0.0251 > 0.025$ ✗

$p(X \leq 1238) = 0.0223 < 0.025$ ✓

$\therefore$ largest value of n is 1239