Clear zone — margin trimmed off after completion of assessment

LUI | | | | | | | | | | School code | | | |

School name

Given name/s

Family name

Attach your
barcode ID label here

Book of books used

External assessment 2025

Question and response book

Specialist Mathematics

Paper 2 — Technology-active

Time allowed

- Perusal time — 5 minutes
- Working time — 90 minutes

General instructions

- Answer all questions in this question and response book.
- QCAA-approved calculator **permitted**.
- QCAA formula book provided.
- Planning paper will not be marked.

Section 1 (10 marks)

- 10 multiple choice questions

Section 2 (50 marks)

- 8 short response questions

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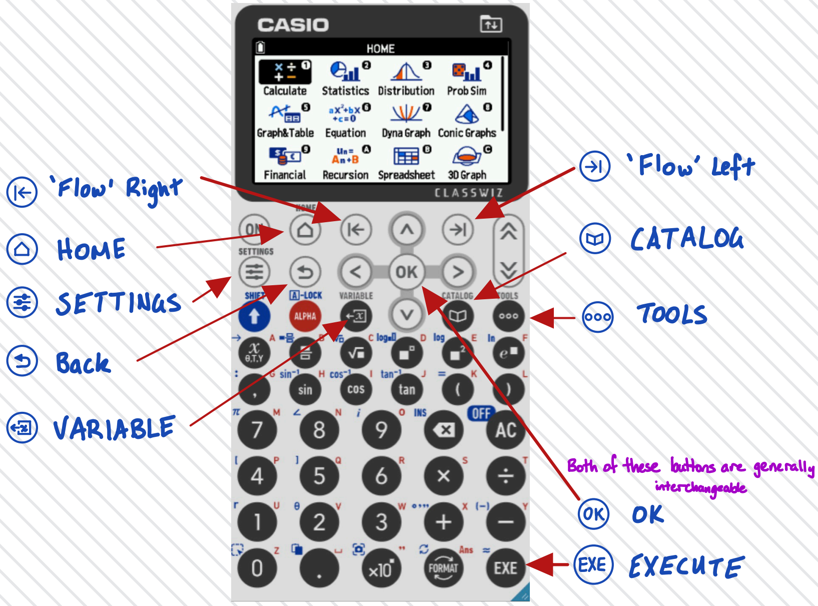
Sample Solutions (unofficial)

- Suggested student response in black
  e.g. what students could write down.
- Use of CASIO *fx-1AU GRAPH* in blue.
- Notes not part of the solution in pink
  e.g. helpful hints and thoughts



Section 1

Instructions

- This section has 10 questions and is worth 10 marks.
- Use a 2B pencil to fill in the A, B, C or D answer bubble completely.
- Choose the best answer for Questions 1–10.
- If you change your mind or make a mistake, use an eraser to remove your response and fill in the new answer bubble completely.

	A	B	C	D
Example:	●	○	○	○

	A	B	C	D
1.	○	○	●	○
2.	○	○	○	●
3.	○	●	○	○
4.	○	○	○	●
5.	○	●	○	○
6.	○	●	○	○
7.	●	○	○	○
8.	○	○	○	●
9.	○	●	○	○
10.	○	○	●	○

Ensure you have filled an answer bubble for each question.

Do not write outside this box.

Section 2

Instructions

- Write using black or blue pen.
- Questions worth more than one mark require mathematical reasoning and/or working to be shown to support answers.
- If you need more space for a response, use the additional pages at the back of this book.
  - On the additional pages, write the question number you are responding to.
  - Cancel any incorrect response by ruling a single diagonal line through your work.
  - Write the page number of your alternative/additional response, i.e. See page …
  - If you do not do this, your original response will be marked.
- This section has eight questions and is worth 50 marks.

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QUESTION 11 (4 marks) Calculator

The mass of checked bags that passengers take on a Brisbane–Sydney flight is normally distributed with a mean of 21.3 kg and a standard deviation of 4.2 kg.

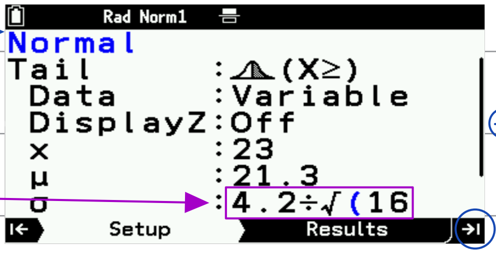
A random sample of 16 checked bags was conducted.

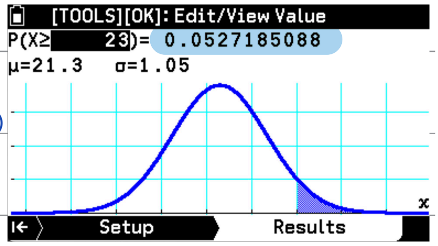
a) Determine the probability that the mean mass of the checked bags for this sample exceeds 23 kg. *[2 marks]*

$\sigma_{\bar{X}} = \frac{\sigma}{\sqrt{n}} = \frac{4.2}{\sqrt{16}} = 1.05$

sample means	mean	μ
	standard deviation	$\frac{\sigma}{\sqrt{n}}$

Distribution, Normal →



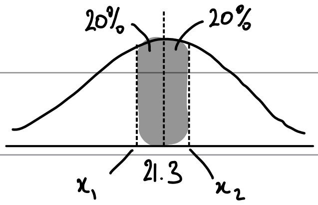


These fields accept calculations.

$\therefore \Pr(X > 23) \approx 0.0527$

There is a 40% probability that the mean mass of the checked bags for this sample is within $\pm m$ kg of the population mean. $= 21.3$

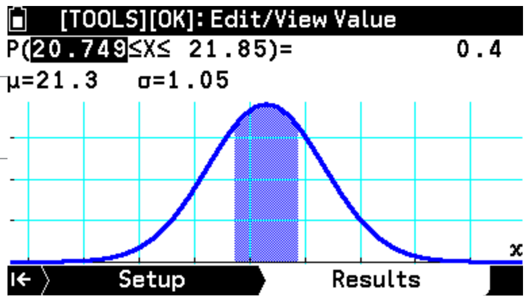
b) Determine the value of m. *[2 marks]*



$\Pr(21.3 - m \le \bar{X} \le 21.3 + m) = 0.4$

While looking at graph of the normal distribution from before, the values and tail options are editable:

2 Tail, 2 $\le x \le$, >, >, type 0.4, OK



$\therefore 21.3 - m = 20.749$ and $21.3 + m = 21.85$

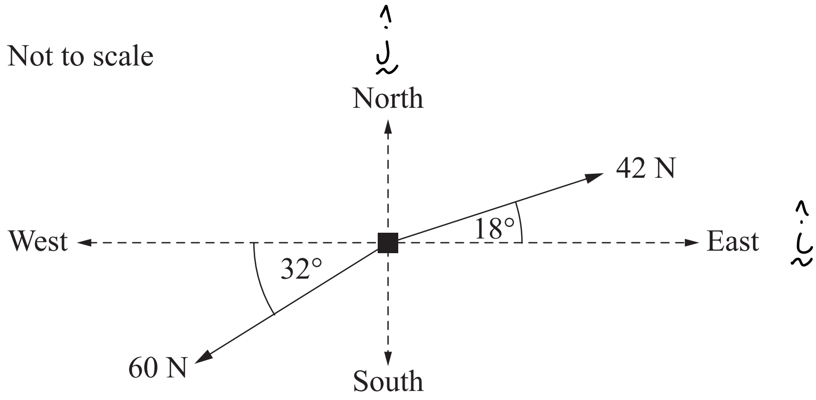
$\therefore m = 0.551$

Do not write outside this box.

QUESTION 12 (7 marks) Calculator ⊜, Angle, Degree, OK, Complex Mode, a+bi

A 10 kg object is travelling at ground level with a constant velocity.

At an instant, two forces of 60 N and 42 N act simultaneously on the object parallel to the ground in the directions shown.



Let unit vectors in the east and north directions be $\hat{i}$ and $\hat{j}$ respectively.

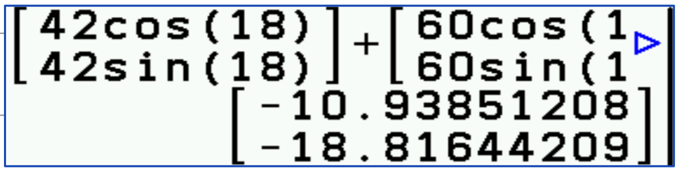
a) Determine the resultant force acting on the object expressed in Cartesian form. Simplify your answer. *[2 marks]*

Resolve forces into components. Go to the calculate app: ⌂, Calculate, OK

To input a vector without saving: ⊙⊙⊙, mxn

$$\begin{bmatrix} 42\cos 18 \\ 42\sin 18 \end{bmatrix} + \begin{bmatrix} 60\cos(180+32) \\ 60\sin(180+32) \end{bmatrix} \approx \begin{bmatrix} -10.94 \\ -18.82 \end{bmatrix}$$

$$\therefore \ F = -10.94\hat{i} - 18.42\hat{j}$$

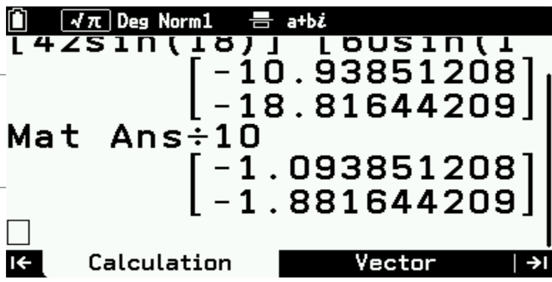


b) Determine the acceleration of the object after the forces act. Leave your answer in Cartesian form. *[1 mark]*

$$F = ma \longrightarrow a = \frac{F}{m} = \frac{-10.94\hat{i} - 18.82\hat{j}}{10}$$

$$= -1.09\hat{i} - 1.88\hat{j}$$

Just press '÷10' and the Mat Ans automatically appears:



Do not write outside this box.

The object is initially travelling at 5 m s^{-1} in a northerly direction when the forces act. $\to 5\hat{\underset{\sim}{j}}$

c) Determine an expression for the object's velocity in terms of time, t, after the forces act. Leave your answer in Cartesian form. *[2 marks]*

$$\underset{\sim}{v}(t) = \int \underset{\sim}{a}\,dt = \int -1.09\hat{\underset{\sim}{i}} - 1.88\hat{\underset{\sim}{j}}\ dt$$

$$= -1.09t\hat{\underset{\sim}{i}} - 1.88t\hat{\underset{\sim}{j}} + c$$

$t=0,\ v = 5\hat{\underset{\sim}{j}}$ $\quad \therefore v(t) = -1.09t\hat{\underset{\sim}{i}} - 1.88t\hat{\underset{\sim}{j}} + 5\hat{j}$

$$= -1.09t\hat{\underset{\sim}{i}} + (5-1.88t)\hat{\underset{\sim}{j}}$$

d) Calculate the speed of the object after the forces have been acting for two seconds. *[2 marks]*

$$\underset{\sim}{v}(2) = -2.18\hat{\underset{\sim}{i}} + 1.24\hat{\underset{\sim}{j}}$$

Speed $= |\underset{\sim}{v}(2)| = \sqrt{(-2.18)^2 + (1.24)^2}$

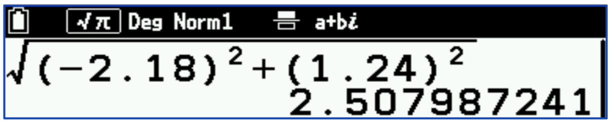
$= \dfrac{\sqrt{629}}{10}$

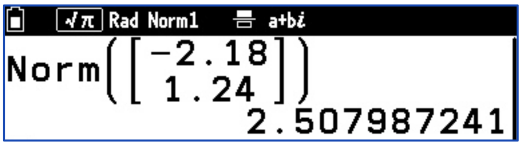
Press FORMAT for decimal $\approx 2.51\ \text{ms}^{-1}$

Alternatively, use Vector Norm for magnitude:

⊞, ⑧ Vector, ⑤ Vector Norm, ⊙⊙⊙, ① mxn, enter dimensions as $m=2$, $n=1$, then confirm,

Input -2.18, ∨, 1.24, EXE





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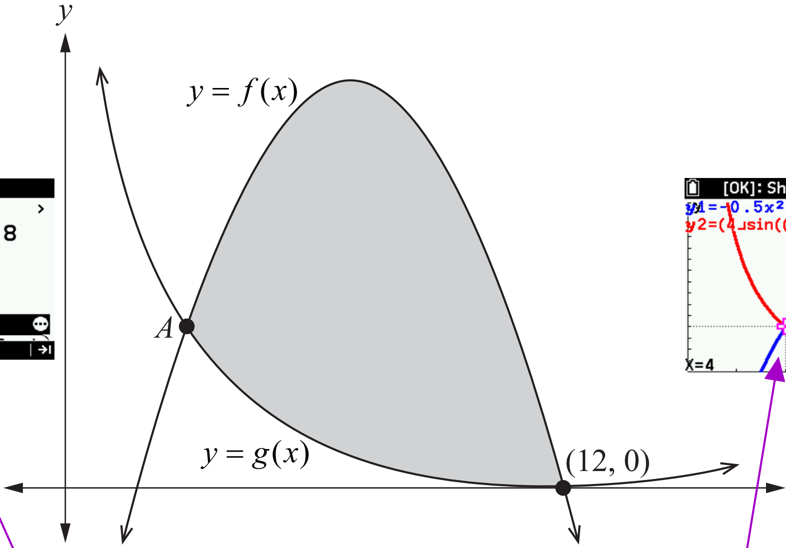
QUESTION 13 (7 marks) Calculator

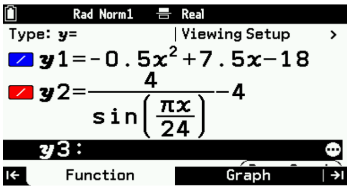
⊜, Angle, Radian

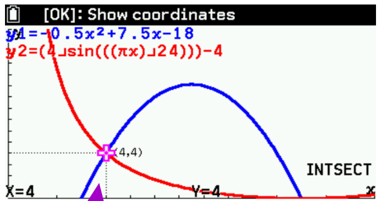
The sketch shows sections of the functions $f(x) = -0.5x^2 + 7.5x - 18$ and $g(x) = 4\operatorname{cosec}\left(\frac{\pi x}{24}\right) - 4$.

Two points of intersection at (12, 0) and point A are shown.

Not to scale







a) Determine the coordinates of point A. *[1 mark]*

⌂, Graph&Table, input both functions, ⇥, set window to: $0 \le x \le 15$ and $0 \le y \le 15$.

⋯, ② Graph Solve, ④ Intersection, use left and right arrows to find A. $A = (4, 4)$

Consider the shaded bounded region between the functions.

b) Determine an approximate area of this region using Simpson's rule with four intervals. Show evidence of the values substituted into this rule in your solution. *[3 marks]*

Simpson's rule	$\int_a^b f(x)\,dx \approx \frac{w}{3}\left[f(x_0)+4\left[f(x_1)+f(x_3)+\ldots\right]+2\left[f(x_2)+f(x_4)+\ldots\right]+f(x_n)\right]$ where $w = \frac{b-a}{n}$

Let $y_1 = f(x)$, $y_2 = g(x)$, $y_3 = y_1 - y_2$

(un select y_1 and y_2 optional)

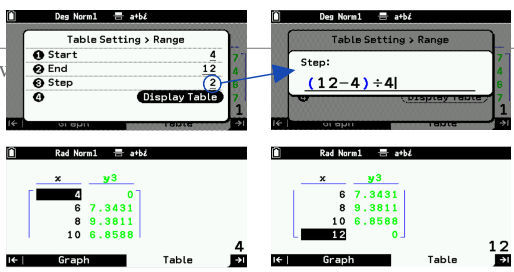
⤺ to Graph & Table setup, ensure y_3 is selected and input the difference function:

⊞, ② Function, ① y1, OK, — (minus sign), ⊞, ② Function, ② y2, OK

Press down to Display Table, OK

⋯, ① Set Table Domain, ① Range.

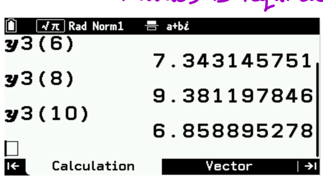
Input values as shown. These fields also accept calculations.



Alternatively, now that y3 is setup, we can use it like function notation in Calculate.

⌂, Calculate, ⊞, ② Function, ③ y3, (, 4,), EXE.

Use the values and interval width to construct a table, as evidence of values is required.



You can use function notation directly in formula, but the question asks for evidence.

$\frac{\frac{12-4}{4}}{3}(y3(4)+4(y3(6)+y(10))+2(y3(8))+y3(12))$

50.38037321

This table showing the values can be implied by subsequent working.

	x	$y3$
x_0	4	0
x_1	6	7.3431
x_2	8	9.3811
x_3	10	6.8588
x_4	12	0

$\therefore \int_4^{12} f(x) - g(x)\, dx \approx \frac{2}{3}\left[0 + 4(7.3431+6.8588) + 2(9.3811) + 0\right)$

$\approx 50.38 \text{ units}^2$

c) State a definite integral that represents the area of the shaded bounded region. *[1 mark]*

$\int_4^{12} (-0.5x^2 + 7.5x - 18) - \left(4\operatorname{cosec}\left(\frac{\pi x}{24}\right) - 4\right) dx$

d) Determine the value of your result from Question 13c). Give your answer to two decimal places. *[1 mark]*

" Un-select y3 "   " Area between curves " starts here

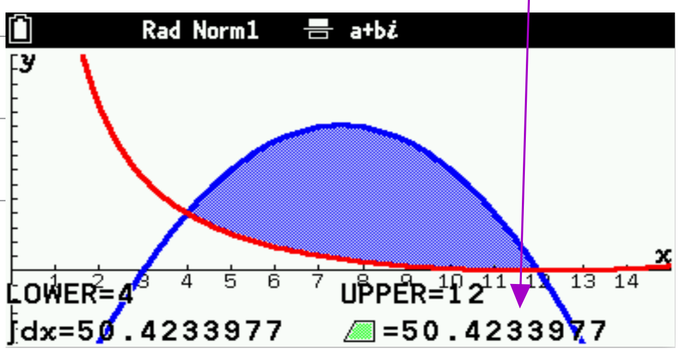
$\underbrace{}$ ⌂, Graph&Table, highlight y3, ⋯, ① Select, OK, ↶, ⇥, ① Draw, ⋯, ② Graph Solve,

⑤ ∫dx, ③ Intersection, Press > until the first intersection (4,4), OK, >, OK, ▱ = 50.42

A = 50.42 using GC.

e) Other than working to more decimal places, state a strategy involving Simpson's rule that could be used to improve the accuracy of your result from Question 13b). *[1 mark]*

Use more intervals



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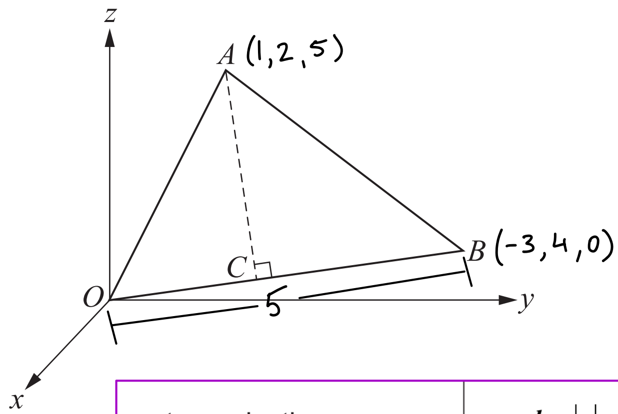
QUESTION 14 (8 marks) Calculator

The origin, O, is joined to points $A(1, 2, 5)$ and $B(-3, 4, 0)$ to form triangle OAB.

Point C is the point on OB such that AC is perpendicular to OB, as shown.

Not to scale



vector projection	$\boldsymbol{a}$ on $\boldsymbol{b} = \lvert\boldsymbol{a}\rvert\cos(\theta)\hat{\boldsymbol{b}} = (\boldsymbol{a}\cdot\hat{\boldsymbol{b}})\hat{\boldsymbol{b}} = \left(\frac{\boldsymbol{a}\cdot\boldsymbol{b}}{\boldsymbol{b}\cdot\boldsymbol{b}}\right)\boldsymbol{b}$

a) Given the length of side OB is 5 units, show that the vector projection of

$\overrightarrow{OA}$ on $\overrightarrow{OB}$ is $\frac{1}{5}\begin{pmatrix}-3\\4\\0\end{pmatrix}$. *[2 marks]*

Usually implies working must be shown.

$$\text{proj}_{\underset{\sim}{b}}\underset{\sim}{a} = (\underset{\sim}{a}\cdot\hat{\underset{\sim}{b}})\hat{\underset{\sim}{b}}$$

$$= \left[\begin{pmatrix}1\\2\\5\end{pmatrix}\cdot\frac{1}{5}\begin{pmatrix}-3\\4\\0\end{pmatrix}\right]\frac{1}{5}\begin{pmatrix}-3\\4\\0\end{pmatrix}$$

Factor $\frac{1}{5}$

$$= \frac{1}{25}\left(\underset{\text{Dot product: } \underset{\sim}{a}\cdot\underset{\sim}{b}}{-3+8+0}\right)\begin{pmatrix}-3\\4\\0\end{pmatrix}$$

$$= \frac{1}{25}(5)\begin{pmatrix}-3\\4\\0\end{pmatrix} = \frac{1}{5}\begin{pmatrix}-3\\4\\0\end{pmatrix}$$

b) Use your result from Question 14a) to determine the length of OC. *[1 mark]*

$\overrightarrow{OC} = \text{proj}_{\underset{\sim}{b}}\underset{\sim}{a}$, $\quad |\overrightarrow{OC}| = \text{Norm}\left(\frac{1}{5}\begin{pmatrix}-3\\4\\0\end{pmatrix}\right) = 1$

(book), ⑧ Vectors, ⑤ Vector Norm

(ooo), ① m×n, m=3 n=1, (OK)

Do not write outside this box.

c) Determine the length of side *OA*. *[1 mark]*

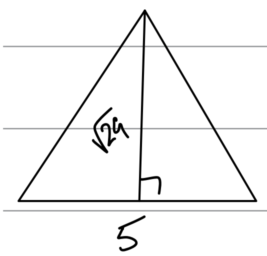
$|\overrightarrow{OA}| = \text{Norm}\left(\begin{bmatrix}1\\2\\5\end{bmatrix}\right) = \sqrt{30}$

As above

d) Use Pythagoras' theorem to determine the length of *AC*. *[1 mark]*

$$|\overrightarrow{AC}| = \sqrt{|\overrightarrow{OA}|^2 - |\overrightarrow{OC}|^2}$$
$$= \sqrt{(\sqrt{30})^2 - (1)^2}$$
$$= \sqrt{30-1}$$
$$= \sqrt{29}$$

e) Use your result from Question 14d) to determine the area of triangle *OAB*. *[1 mark]*

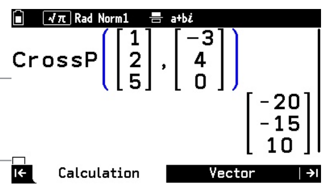


$$A = \frac{1}{2}bh = \frac{1}{2} \times 5 \times \sqrt{29} = \frac{5\sqrt{29}}{2}$$

f) Use a vector product method to verify your result from Question 14e). *[2 marks]*

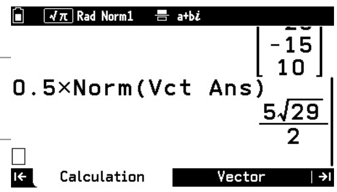
$$\text{Area} = \frac{1}{2}\left|\overrightarrow{OA} \times \overrightarrow{OB}\right|$$

Cross Product: ⊞, ⑧ Vector, ② Cross Product



$= 0.5 \times \underbrace{\text{Norm}(\text{Vct Ans})}$

⊞, ⑧ Vectors, ⑤ Vector Norm, ⊞, ⑧ Vectors, ① Vct, ALPHA, FORMAT ANS .



$$= \frac{1}{2}\left|\begin{bmatrix}-20\\-15\\10\end{bmatrix}\right|$$ Show evidence of Cross Product

$$= \frac{5\sqrt{29}}{2}$$

Do not write outside this box.

QUESTION 15 (6 marks) Non-Calculator

De Moivre's theorem can be expressed as

$$\left(r\left(\cos(\theta)+i\sin(\theta)\right)\right)^n = r^n\left(\cos(n\theta)+i\sin(n\theta)\right)\ \forall n \in Z^+$$

Prove De Moivre's theorem using mathematical induction.

Prove true for $n=1$:

$r(\cos\theta + i\sin\theta) = r(\cos\theta + i\sin\theta)$

$r\,\text{cis}\,\theta = r\,\text{cis}\,\theta$ ✓ True as LHS = RHS

Assume true for $n=k$

$(r\,\text{cis}\,\theta)^k = r^k\,\text{cis}(k\theta)$

Prove true for $n=k+1$

$(r\,\text{cis}\,\theta)^{k+1} = r^{k+1}(\text{cis}((k+1)\theta)$

Expand LHS using index laws.

$\underbrace{(r\,\text{cis}\,\theta)^k}_{\text{Use assumption statement}}(r\,\text{cis}\,\theta) = r^{k+1}\,\text{cis}((k+1)\theta)$

$r^k\,\text{cis}(k\theta)(r\,\text{cis}\,\theta) = r^{k+1}\,\text{cis}((k+1)\theta)$

$r^k(\cos k\theta + i\sin k\theta) \times r(\cos\theta + i\sin\theta) = r^{k+1}\,\text{cis}((k+1)\theta)$

$LHS = r^{k+1}(\cos(k\theta)\cos(\theta) + i\cos(k\theta)\sin(\theta) + i\sin(k\theta)\cos(\theta) + i^2\sin(k\theta)\sin(\theta)$

$= r^{k+1}(\cos(k\theta)\cos\theta - \sin(k\theta)\sin(\theta) + i(\cos(k\theta)\sin(\theta) + \sin(k\theta)\cos(\theta)))$

angle sum and difference identities	$\sin(A+B)=\sin(A)\cos(B)+\cos(A)\sin(B)$ $\sin(A-B)=\sin(A)\cos(B)-\cos(A)\sin(B)$ $\cos(A+B)=\cos(A)\cos(B)-\sin(A)\sin(B)$ $\cos(A-B)=\cos(A)\cos(B)+\sin(A)\sin(B)$

$= r^{k+1}(\cos(k\theta+\theta) + i\sin(k\theta+\theta))$

Do not write outside this box.

$= r^{k+1}\left(\cos(\theta(k+1)) + i\sin(\theta(k+1))\right)$

$= r^{k+1}\operatorname{cis}((k+1)\theta) \quad = RHS$

True for $n=k+1$,

$\therefore$ The proposition is true by mathematical induction.

Do not write outside this box.

QUESTION 16 (6 marks) Calculator

A certain population can be approximately modelled by the differential equation

$$\frac{dP}{dt} = 0.5P(1 - 0.2P)$$

where P is the population in millions and t is the number of years since 1 January 2025.

Given that the population on 1 January 2025 was estimated at 0.3 million, use a calculus approach to estimate the population on 1 January 2030. Find P when $t = 5$.

$$\frac{dP}{dt} = 0.5P(1-0.2P)$$

$$\int \underbrace{\frac{1}{P(1-0.2P)}}_{\text{Partial fractions}} \, dP = \int 0.5 \, dt$$

$$\frac{1}{P(1-0.2P)} = \frac{A}{P} + \frac{B}{1-0.2P}$$

$$1 = A(1-0.2P) + BP$$

Let $P=0$, $1 = A(1-0) + 0$

$1 = A$

Determine what P value to use next: SolveN$(1-0.2x = 0)$, $x = 5$

Let $P = 5$, $1 = A(1 - 0.2\times5) + 5B$

$1 = 5B$

$\frac{1}{5} = B = 0.2$

$$\therefore \int \frac{1}{P} + \frac{0.2}{1-0.2P} \, dP = \int 0.5 \, dt$$

$$\ln|P| - \ln|1-0.2P| = 0.5t + c$$

Do not write outside this box.

$t = 0, \quad P = 0.3$

$$\ln(0.3) - \ln(1 - 0.2 \times 0.3) = 0 + C$$

OPTIONAL: Store c as ALPHA c to minimise rounding errors.

```
√π Rad Norm1   a+bi
ln(0.3)−ln(1−0.2×0.3▷
            -1.142097401
Ans→C
            -1.142097401
```

SHIFT, →, A

$$\therefore \ln(P) - \ln(1 - 0.2P) = 0.5t - 1.14$$

Determine P when $t = 5$ using Solve N.

$$\text{SolveN}(\ln(P) - \ln(1 - 0.2P) = 0.5(5) + C)$$

$$P \approx 2.187$$

②, Function Analysis, ⑤ SolveN   ALPHA, C

```
SolveN(ln(x)−ln(1−0.▷
           {2.187228212}
```

The estimated population after 5 years is 2.19 million.

Do not write outside this box.

QUESTION 17 (5 marks) Calculator

A variable, X, is assumed to be normally distributed with $\mu = 24.311$ and $\sigma = 5.102$.

Two 90% confidence intervals for μ were calculated from two different random samples from X, with the second sample being smaller than the first sample by 60. 1st sample size $= n$, 2nd sample $(n-60)$

Both confidence intervals were calculated using the population standard deviation rather than their respective sample standard deviations. $\sigma = 5.102$

The confidence interval produced from the first sample was (23.560, 25.498).

Determine the probability that the confidence interval produced from the second sample overlaps the confidence interval from the first sample.

First sample: $(23.56, 25.498)$ with 90% confidence interval

$$E = z\frac{s}{\sqrt{n}}$$

approximate margin of error	$E = z\frac{s}{\sqrt{n}}$

$$\bar{x}_1 = \frac{23.56 + 25.498}{2} = 24.529$$

$$E = 24.529 - 23.56 = 0.969$$

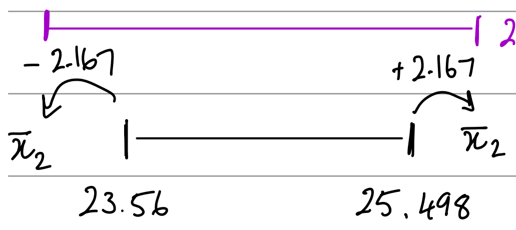
90% z-value

$$\text{SolveN}\left(0.969 = 1.645\frac{5.102}{\sqrt{n_1}}\right) \rightarrow n_1 = 75.017944$$

First sample size was $n_1 = 75 \therefore n_2 = 75 - 60 = 15$

Error for second sample: $E_2 = z\frac{s}{\sqrt{n}} = 1.645 \times \frac{5.102}{\sqrt{15}}$

$$E_2 \approx 2.167$$



2nd C.I. will overlap with the first if $\bar{x}_2$ is between 21.393 and 27.665

$23.56 - 2.167 = 21.393$

$25.498 + 2.167 = 27.665$

Do not write outside this box.

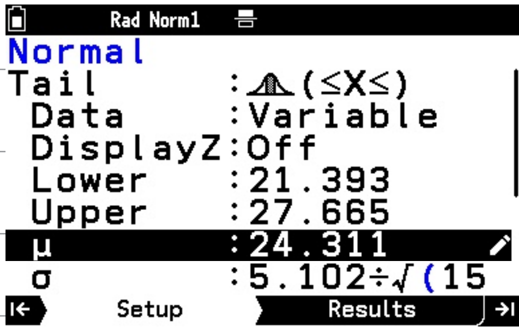
$X \sim N(\mu, \sigma)$

Sample 2: $X \sim N\left(24.311, \frac{5.102}{\sqrt{15}}\right)$

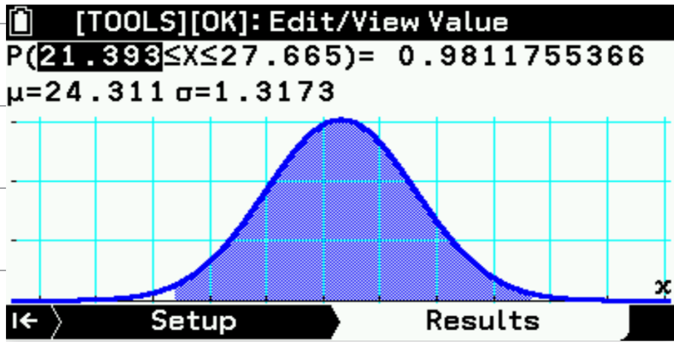
sample means	mean	μ
	standard deviation	$\frac{\sigma}{\sqrt{n}}$

Determine $Pr(21.393 \leq X \leq 27.665)$ using normal distribution.

⌂, Distribution, Normal,



, ⇥ to results



$Pr(21.393 \leq X \leq 27.665) = 0.9812$

The probability that the confidence intervals overlap is 98.12%

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QUESTION 18 (7 marks) Non-Calculator

Polar curves are defined by points that are a variable distance of r units from the origin and dependent on the angle θ (in radians) measured from the positive x-axis.

Consider the polar curve $r = 1 + \cos(\theta)$.

A table of four polar coordinates on this curve is shown.

θ	r
0	2
$\frac{\pi}{6}$	$1+\frac{\sqrt{3}}{2}$
$\frac{\pi}{3}$	1.5
$\frac{\pi}{2}$	1

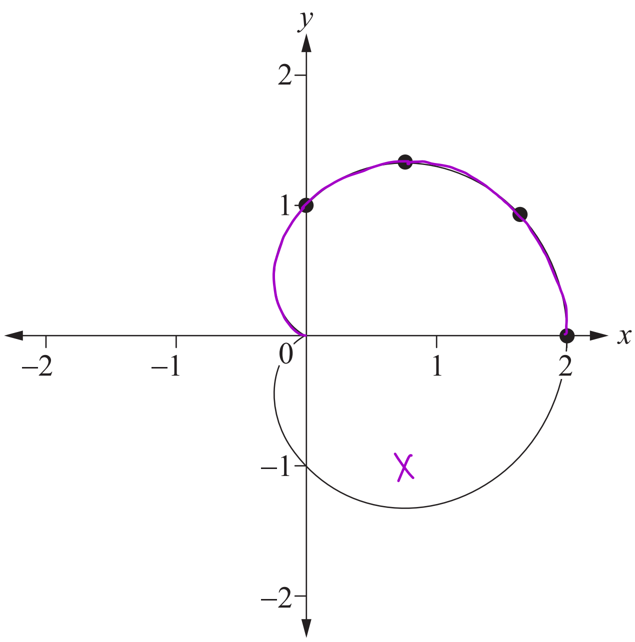
$r = 1+\cos(0) = 1+1 = 2$

$r = 1+\cos(\pi/6) = 1+\frac{\sqrt{3}}{2}$

$r = 1+\cos(\pi/3) = 1+\frac{1}{2} = 1.5$

$r = 1+\cos(\pi/2) = 1+0 = 1$

The graph shows the polar curve $r = 1 + \cos(\theta)$ for $0 \le \theta \le 2\pi$ on a Cartesian plane. The polar coordinates from the table have been plotted on the curve.



The length of a polar curve, L, from $\theta = a$ to $\theta = b$ can be determined using the rule

$$L = \int_a^b \sqrt{r^2 + \left(\frac{dr}{d\theta}\right)^2}\, d\theta$$

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Use a complete algebraic method to determine the length of the section of the given polar curve that lies above the x-axis.

$0 \leq \theta \leq \pi$

$$L = \int_0^{\pi} \sqrt{r^2 + \left(\frac{dr}{d\theta}\right)^2}\, d\theta$$

If $r = 1 + \cos\theta$, $\frac{dr}{d\theta} = -\sin\theta$, $r^2 = (1+\cos\theta)^2$

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

$$\left(\frac{dr}{d\theta}\right)^2 = \sin^2\theta$$

$$\therefore\ L = \int_0^{\pi} \sqrt{1 + 2\cos\theta + \underbrace{\cos^2\theta + \sin^2\theta}_{1}}\, d\theta$$

using Pythagorean identity

$$= \int_0^{\pi} \sqrt{2 + 2\cos\theta}\, d\theta$$

$$= \int_0^{\pi} \sqrt{2(1+\cos\theta)}\, d\theta$$

$$= \int_0^{\pi} \sqrt{2}\sqrt{1+\cos\theta}\, d\theta$$

$\theta = 2A \rightarrow A = \frac{\theta}{2}$

double-angle identities	$\sin(2A) = 2\sin(A)\cos(A)$ $\cos(2A) = \cos^2(A) - \sin^2(A)$ $= 1 - 2\sin^2(A)$ $= 2\cos^2(A) - 1$

$$= \sqrt{2}\int_0^{\pi} \sqrt{1 + \left(2\cos^2\left(\frac{\theta}{2}\right) - 1\right)}\, d\theta$$

Use this identity to eventually cancel the square root.

$$= \sqrt{2}\int_0^{\pi} \sqrt{2\cos^2\left(\frac{\theta}{2}\right)}\, d\theta$$

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$$= \sqrt{2}\sqrt{2}\int_0^{\pi} \cos\left(\frac{\theta}{2}\right)\, d\theta$$

$$= 2\left[2\sin\left(\theta/2\right)\right]_0^{\pi}$$

$$= 2\left(2\sin(\pi/2) - 2\sin(0)\right)$$

$$= 2(2-0)$$

$= 4$ units $\longrightarrow$ Can confirm with G.C. $\int_0^{\pi} \sqrt{2+2\cos\theta}\, d\theta = 4$

END OF PAPER

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ADDITIONAL PAGE FOR STUDENT RESPONSES

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