2024
VCE
Mathematical Methods
Year 12
Trial Examination 2
Detailed Answers

Kilbaha Education

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SECTION A

ANSWERS

1	**A**	B	C	D
2	A	B	**C**	D
3	**A**	B	C	D
4	A	**B**	C	D
5	A	B	**C**	D
6	A	**B**	C	D
7	A	B	C	**D**
8	**A**	B	C	D
9	A	B	**C**	D
10	**A**	B	C	D
11	A	B	C	**D**
12	A	**B**	C	D
13	A	**B**	C	D
14	A	**B**	C	D
15	A	B	C	**D**
16	A	B	**C**	D
17	A	B	C	**D**
18	A	B	C	**D**
19	A	B	**C**	D
20	**A**	B	C	D

SECTION A

Question 1 **Answer A**

Both functions have periods $T = \dfrac{2\pi}{\frac{\pi}{c}} = 2c$, both functions have an amplitude of b,

both functions have a range of $[a-b, a+b]$

Question 2 **Answer C**

$f(x) = \log_e(b-x)$ domain $b-x>0,\quad x<b$

$g(x) = \sqrt{x+b}$ domain $x+b \ge 0,\quad x \ge -b$,

domain of $\dfrac{f}{g} = -b < x < b = (-b, b)$ since $g(x) \ne 0$

Define $f(x)=\ln(b-x)$	*Done*
Define $g(x)=\sqrt{x+b}$	*Done*
$\text{domain}\left(\dfrac{f(x)}{g(x)}, x\right)$	$-b<x<b$

Question 3 **Answer A**

$$\int_0^{4a} f(x)\,dx$$
$$= \int_0^{2a} f(x)\,dx + \int_{2a}^{4a} f(x)\,dx$$
$$= \int_0^{2a} f(x)\,dx - \int_{4a}^{2a} f(x)\,dx$$
$$= \int_0^{2a} f(x)\,dx - \int_{4a}^{2a} f(u)\,du \quad \text{let } u = 4a - x$$
$$= \int_0^{2a} f(x)\,dx + \int_0^{2a} f(4a-x)\,dx = \int_0^{2a} \left(f(x) + f(4a-x)\right)dx$$

reflect in the y-axis

and translate $4a$ units to the right

Define $f(x)=x^3$	*Done*
$\displaystyle\int_0^{4\cdot a} f(x)\,dx$	$64\cdot a^4$
$\displaystyle\int_0^{2\cdot a} (f(x)+f(4\cdot a-x))\,dx$	$64\cdot a^4$

Question 4 **Answer B**

x	1	2	3	4
$f(x) = \dfrac{1}{x}$	1	$\dfrac{1}{2}$	$\dfrac{1}{3}$	$\dfrac{1}{4}$

$a=1,\quad b=4,\quad n=3.\quad h = \dfrac{b-a}{n} = 1$

$$A_T = \frac{h}{2}\left(f(1) + 2\left(f(2)+f(3)\right) + f(4)\right) = \frac{1}{2}\left(1 + 2\left(\frac{1}{2}+\frac{1}{3}\right) + \frac{1}{4}\right) = \frac{35}{24}$$

Question 5 **Answer C**

Consider the function $f: R \to R,\ f(x) = x + 2$.

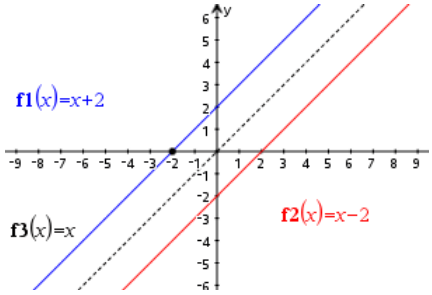
$f: \ y = x + 2$

$f^{-1}: x = y + 2$

$f^{-1}(x) = x - 2$

$f(x) = f^{-1}(x) \Rightarrow x + 2 = x - 2$

This equation is inconsistent, there is no solution, with $y = x$ as all three lines are parallel. Colin is correct.



Consider the function $f: R \to R,\ f(x) = -x^3$.

$f: \quad y = -x^3$

$f^{-1}: \quad x = -y^3 \ , \ y = -x^{\frac{1}{3}} = -\sqrt[3]{x}$

both the function *f* and its inverse have domain and range *R*.

solving $\quad f(x) = f^{-1}(x) \quad \Rightarrow \ (1) \quad -x^3 = -\sqrt[3]{x}$

$(1) \quad x^9 = x \ \Rightarrow x = 0\ , \pm 1$

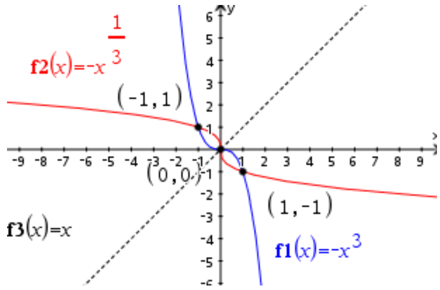
There are three points of intersection between the function and its inverse, with coordinates $(-1,1)$, $(1,-1)$ and the origin $(0,0)$. Only the point at the origin only lies on the line $y = x$. Ben is correct.

Define $f1(x) = -x^3$ Done

solve$(f1(y) = x, y)$ $\quad y = -x^{\frac{1}{3}}$

Define $f2(x) = -x^{\frac{1}{3}}$ Done

solve$(f1(x) = f2(x), x)$ $\quad x = -1$ or $x = 0$ or $x = 1$



Other functions are possible to show that both Ben and Colin are correct.

Question 6 **Answer B**

BR or RB, 2 ways of drawing one red and one blue, without replacement

Box A: $\quad \dfrac{1}{2}\left[\dfrac{(r-1)(b+1)}{(b+r)(b+r-1)} + \dfrac{(b+1)(r-1)}{(b+r)(b+r-1)}\right] = \dfrac{(r-1)(b+1)}{(b+r)(b+r-1)}$

Box B: $\quad \dfrac{1}{2}\left[\dfrac{(r+1)(b-1)}{(b+r)(b+r-1)} + \dfrac{(b-1)(r+1)}{(b+r)(b+r-1)}\right] = \dfrac{(r+1)(b-1)}{(b+r)(b+r-1)}$

Box A or B $\quad \dfrac{(r-1)(b+1)}{(b+r)(b+r-1)} + \dfrac{(r+1)(b-1)}{(b+r)(b+r-1)} = \dfrac{2(br-1)}{(b+r)(b+r-1)}$

$\dfrac{(r-1)\cdot(b+1)+(r+1)\cdot(b-1)}{(r+b)\cdot(r+b-1)} \qquad \dfrac{2\cdot(b\cdot r-1)}{(r+b)\cdot(r+b-1)}$

Question 7 **Answer D**

When $n=2$, $y=\sqrt{x-a}$, $\frac{dy}{dx}=\frac{1}{2\sqrt{x-a}}$

When $n=-3$,

$y=\frac{1}{\sqrt[3]{x-a}}=(x-a)^{-\frac{1}{3}}$, $\frac{dy}{dx}=-\frac{1}{3}(x-a)^{-\frac{4}{3}}$

When $n=-\frac{1}{2}$, $y=\frac{1}{(x-a)^2}$, $\frac{dy}{dx}=-\frac{2}{(x-a)^3}$

All of **A. B** and **C.** are not differentiable at $x=a$.

When $n=\frac{1}{2}$, $y=(x-a)^2$ is differentiable at $x=a$

Define $f(x)=(x-a)^{\frac{1}{n}}|n=2$ Done

$\frac{d}{dx}(f(x))|x=a$ undef

Define $f(x)=(x-a)^{\frac{1}{n}}|n=-3$ Done

$\frac{d}{dx}(f(x))|x=a$ undef

Define $f(x)=(x-a)^{\frac{1}{n}}|n=\frac{-1}{2}$ Done

$\frac{d}{dx}(f(x))|x=a$ undef

Define $f(x)=(x-a)^{\frac{1}{n}}|n=\frac{1}{2}$ Done

$\frac{d}{dx}(f(x))|x=a$ 0

Question 8 **Answer A**

$$y=4\tan\left(2\left(x-\frac{\pi}{3}\right)\right)=\frac{4\sin\left(2\left(x-\frac{\pi}{3}\right)\right)}{\cos\left(2\left(x-\frac{\pi}{3}\right)\right)}$$

crosses the x-axis when $y=0$ so $\sin\left(2\left(x-\frac{\pi}{3}\right)\right)=0$

has vertical asymptotes when $\cos\left(2\left(x-\frac{\pi}{3}\right)\right)=0$

$\text{solve}\left(\sin\left(2\cdot\left(x-\frac{\pi}{3}\right)\right)=0,x\right)$ $\quad x=\frac{(3\cdot n1-1)\cdot\pi}{6}$ $\quad x=\frac{(3\cdot(k+1)-1)\cdot\pi}{6}$ $\quad x=\frac{(3\cdot k+2)\cdot\pi}{6}$

$\text{solve}\left(\cos\left(2\cdot\left(x-\frac{\pi}{3}\right)\right)=0,x\right)$ $\quad x=\frac{(6\cdot n2-5)\cdot\pi}{12}$ $\quad x=\frac{(6\cdot(k-1)-5)\cdot\pi}{12}$ $\quad x=\frac{(6\cdot k-11)\cdot\pi}{12}$

Question 9 **Answer C**

$$\Pr(X \ge 2) = 1 - [\Pr(X=1) + \Pr(X=0)] = 1 - \left[\binom{10}{1} 0.37 \times 0.63^9 + 0.63^{10}\right]$$

$n=10,\ q=0.63,\ p=0.37$, at least two successes in ten trials each with a probability of 0.37

Question 10 **Answer A**

$$\left(\hat{p} - z\sqrt{\frac{\hat{p}(1-\hat{p})}{n}}\ ,\ \hat{p} + z\sqrt{\frac{\hat{p}(1-\hat{p})}{n}}\right)$$

z95:=invNorm(0.975,0,1)	1.9600
z99:=invNorm(0.995,0,1)	2.5758

$CI:\quad 99\%,\quad z = 2.5758 \quad \left(\hat{p} - 2.5758\sqrt{\frac{\hat{p}(1-\hat{p})}{n}}\ ,\ \hat{p} + 2.5758\sqrt{\frac{\hat{p}(1-\hat{p})}{n}}\right) = (a,b)$

$(1)\ a = \hat{p} - 2.5758\sqrt{\frac{\hat{p}(1-\hat{p})}{n}} \qquad (2)\ b = \hat{p} + 2.5758\sqrt{\frac{\hat{p}(1-\hat{p})}{n}}$

$\frac{1}{2}((1)+(2)) \quad \hat{p} = \frac{a+b}{2}, \qquad \frac{1}{2}((2)-(1)) \quad \sqrt{\frac{\hat{p}(1-\hat{p})}{n}} = \frac{b-a}{2\times 2.5758}$

$CI:\quad 95\%,\quad z = 1.96$

$$\left(\hat{p} - 1.96\sqrt{\frac{\hat{p}(1-\hat{p})}{n}}\ ,\ \hat{p} + 1.96\sqrt{\frac{\hat{p}(1-\hat{p})}{n}}\right)$$

$$\left(\frac{a+b}{2} - \frac{1.96(b-a)}{2\times 2.5758}, \frac{a+b}{2} + \frac{1.96(b-a)}{2\times 2.5758}\right)$$

$$\left(\frac{a}{2}\left(1+\frac{1.96}{2.5758}\right) + \frac{b}{2}\left(1-\frac{1.96}{2.5758}\right)\ ,\ \frac{a}{2}\left(1-\frac{1.96}{2.5758}\right) + \frac{b}{2}\left(1+\frac{1.96}{2.5758}\right)\right)$$

$(0.88a + 0.12b,\ 0.12a + 0.88b)$

zInterval_1Prop 20,100,0.99: *stat.results*

"Title"	"1−Prop z Interval"
"CLower"	0.097
"CUpper"	0.303
"p̂"	0.200
"ME"	0.103
"n"	100.000

0.88· *stat.CLower*+0.12· *stat.CUpper*	0.122
0.12· *stat.CLower*+0.88· *stat.CUpper*	0.278

zInterval_1Prop 20,100,0.95: *stat.results*

"Title"	"1−Prop z Interval"
"CLower"	0.122
"CUpper"	0.278
"p̂"	0.200
"ME"	0.078
"n"	100.000

Question 11 **Answer D**

$f(x)=g(x)e^{g(x)}$ using the product rule

$f'(x)=\frac{d}{dx}(g(x))\times e^{g(x)}+g(x)\frac{d}{dx}\left(e^{g(x)}\right)$

$f'(x)=g'(x)e^{g(x)}+g(x)g'(x)e^{g(x)}$

$f'(x)=g'(x)e^{g(x)}(1+g(x))$

$f'(2)=g'(2)e^{g(2)}(1+g(2))=3e^{4}(1+4)$

$f'(2)=15e^{4}$

Question 12 **Answer B**

$f(x)=\int g(x)\,dx \quad \Rightarrow \quad g(x)=\frac{d}{dx}(f(x))=f'(x)$

$h(x)=\frac{d}{dx}(g(x))=\frac{d}{dx}(f'(x))$

Question 13 **Answer B**

$n=18,\quad \hat{P}=\frac{X}{18} \qquad X\stackrel{d}{=}Bi(n=18,p=?)$

$\Pr\left(\hat{P}=\frac{1}{3}\right)=\Pr(X=6)=\binom{18}{6}p^{6}(1-p)^{12}=0.1873$

solving gives $p=0.3$,

$\Pr\left(\hat{P}<\frac{1}{2}\right)=\Pr(X<9)$

$=\Pr(X\le 8)=0.940$

$\text{solve}\left(\text{nCr}(18,6)\cdot p^{6}\cdot(1-p)^{12}=0.1873,p\right)|0<p<0.35$ $p=0.3000$

$\text{binomCdf}(18,0.3,0,8)$ 0.9404

Question 14 **Answer B**

If $f(x)$ is a non-zero odd function, then $f(-x)=-f(x)$

Let $f(x)=x^3$, $f(-x)=(-x)^3=-x^3=-f(x)$

$f_o f(x)=f(f(x))=f(x^3)=x^9$ which is an odd function **B.** is true.

All of **A.** **C.** and **D.** are false.

Define $f(x)=x^3$	*Done*
$f(-x)=-f(x)$	true
$f(f(-x))=-f(f(x))$	true
Define $a(x)=f(x^2)\cdot\cos(x)$	*Done*
$a(-x)=-a(x)$	$x^6\cdot\cos(x)=-x^6\cdot\cos(x)$
Define $c(x)=f(x^3)\cdot\sin(x)$	*Done*
$c(-x)=-c(x)$	$x^9\cdot\sin(x)=-x^9\cdot\sin(x)$
Define $d(x)=f(x^2)-f(x)$	*Done*
$d(-x)=-d(x)$	$x^6+x^3=x^3-x^6$

Question 15 **Answer D**

$\sum \Pr(X = x) = 1$ for all p, however since they are probabilities $0 < 1 - \frac{5p}{6} < 1 \Rightarrow 0 < p < \frac{6}{5}$

$$E(X) = \sum x \Pr(X = x) = 1 \times \frac{p}{2} + 2 \times \frac{p}{3} + 3\left(1 - \frac{5p}{6}\right) = \frac{1}{3}(9 - 4p)$$

$$E(X^2) = \sum x^2 \Pr(X = x) = 1 \times \frac{p}{2} + 4 \times \frac{p}{3} + 9\left(1 - \frac{5p}{6}\right) = \frac{1}{3}(27 - 17p)$$

$$\text{Var}(X) = E(X^2) - (E(X))^2 = \frac{p}{9}(21 - 16p) = \frac{1}{9}(21p - 16p^2)$$

for maximum variance $\frac{dV}{dp} = \frac{1}{9}(21 - 32p) = 0, \quad p = \frac{21}{32}$

A. B. C. are all true, **D.** is false

A xv	B pv
1	p/2
2	p/3
3	1−5*p/6

$ex:=\text{sum}(xv \cdot pv)$ $\qquad 3-\frac{4\cdot p}{3}$

$ex2:=\text{sum}(xv^2 \cdot pv)$ $\qquad 9-\frac{17\cdot p}{3}$

$vx:=ex2-ex^2$ $\qquad \frac{7\cdot p}{3}-\frac{16\cdot p^2}{9}$

$\frac{d}{dp}(vx)$ $\qquad \frac{7}{3}-\frac{32\cdot p}{9}$

$\text{solve}\left(\frac{d}{dp}(vx)=0,p\right)$ $\qquad p=\frac{21}{32}$

Question 16 **Answer C**

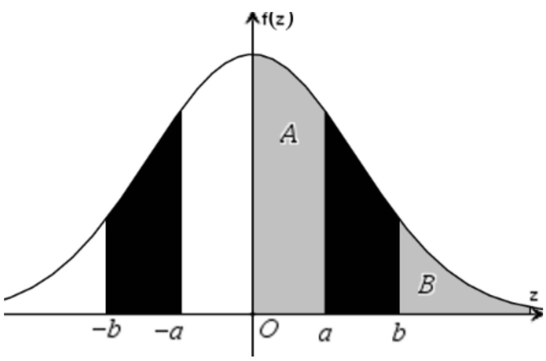
$$\Pr(-b < Z < -a \mid Z < 0)$$

$$= \frac{\Pr(-b < Z < -a)}{\Pr(Z < 0)} = \frac{\Pr(a < Z < b)}{\Pr(Z > 0)} \quad \text{since } 0 < a < b < 3$$

$$= \frac{0.5 - [\Pr(0 < Z < a) + \Pr(Z > b)]}{0.5}$$

$$= \frac{0.5 - (A + B)}{0.5}$$

$$= 1 - 2(A + B)$$



Question 17 **Answer D**

$3x-2y+z=1$

$-x+y-z=2$

Allan stated that the general solution could be expressed as
$x=k,\ \ y=2k-3,\ \ z=k-5$ for $k \in R.$

Ben stated that the general solution could be expressed as
$x=\dfrac{k+3}{2},\ \ y=k,\ \ z=\dfrac{k-7}{2}$ for $k \in R.$

Colin stated that the general solution could be expressed as
$x=k+5,\ \ y=2k+7,\ \ z=k$ for $k \in R.$

All of Allan, Ben and Colin are correct.

$eq1:=3\cdot x-2\cdot y+z=1$	$3\cdot x-2\cdot y+z=1$
$eq2:=^{-}x+y-z=2$	$^{-}x+y-z=2$
$\text{solve}(eq1 \text{ and } eq2,\{y,z\})\vert x=k$	$y=2\cdot k-3 \text{ and } z=k-5$
$\text{solve}(eq1 \text{ and } eq2,\{x,z\})\vert y=k$	$x=\dfrac{k+3}{2} \text{ and } z=\dfrac{k-7}{2}$
$\text{solve}(eq1 \text{ and } eq2,\{x,y\})\vert z=k$	$x=k+5 \text{ and } y=2\cdot k+7$

Question 18 **Answer D**

Newton's method will succeed if the gradient is defined and non-zero at x_0. Only **D.** has $f'(x_0) \neq 0$

$f(x)=\sqrt{3x^2-7x+2},\ \ f'(2)$ is not defined

$f(x)=3x^3-13x^2+16x-4,\ \ f'(2)=0$

$f(x)=(3x-1)\log_e(x-2),\ \ f'(2)$ is not defined

$f(x)=(3x-1)e^{x-2},\ \ f'(2)\neq 0$

Define $fa(x)=\sqrt{3\cdot x^2-7\cdot x+2}$	*Done*
$\dfrac{d}{dx}(fa(x))\vert x=2$	undef
Define $fb(x)=3\cdot x^3-13\cdot x^2+16\cdot x-4$	*Done*
$\dfrac{d}{dx}(fb(x))\vert x=2$	0

Define $fc(x)=(3\cdot x-1)\cdot \ln(x-2)$	*Done*
⚠ $\dfrac{d}{dx}(fc(x))\vert x=2$	undef
Define $fd(x)=(3\cdot x-1)\cdot e^{x-2}$	*Done*
$\dfrac{d}{dx}(fd(x))\vert x=2$	8

Question 19 **Answer C**

iterations	$xleft$	$xmid$	$xright$	$f(xleft).f(xmid)$
0	2	2.5	3	–1.25
1	2	2.25	2.5	–0.0625
2	2	2.125	2.25	0.4844
3	2.125	2.1875	2.25	0.1041

xleft	xmid	xright	f(xleft)*f(xmid)
2.0000	2.5000	3.0000	-1.2500
2.0000	2.2500	2.5000	-0.0625
2.0000	2.1250	2.2500	0.4844
2.1250	2.1875	2.2500	0.1041

```
Define bisection()=
Prgm
maxiter:=4
xleft:=2
xright:=3
Define f(x)=x^2-5
If f(xleft)·f(xright)>0 Then
  Disp "starting values will not converge"
  Return
EndIf
i:=0
Disp " xleft    xmid    xright   f(xleft)· f(xmid)"
While i<maxiter
   xmid:=(xleft+xright)/2
   Disp xleft,xmid,xright,"   ",f(xleft)·f(xmid)
   If f(xleft)·f(xmid)<0 Then
     xright:=xmid
   Else
     xleft:=xmid
   EndIf
  i:=i+1
EndWhile
EndPrgm
```

Question 20 **Answer A**

$\sin^2(x)=\frac{a}{c}$, $\sin(x)=\sqrt{\frac{a}{c}}$, $\cos^2(y)=\frac{b}{c}$, $\cos(y)=\sqrt{\frac{b}{c}}$

since $0<a<b<c<1$, $\sin(x)>0$ and $\cos(y)>0$

$$\log_2(\sin(x)\cos(y))$$

$$=\log_2\left(\sqrt{\frac{a}{c}}\sqrt{\frac{b}{c}}\right)=\log_2\left(\frac{\sqrt{ab}}{c}\right)=\log_2\left(\sqrt{ab}\right)-\log_2(c)$$

$$=\log_e\left((ab)^{\frac{1}{2}}\right)-\log_2(c)=\frac{1}{2}(\log_2(ab))-\log_2(c)$$

$$=\frac{1}{2}(\log_2(a)+\log_2(b))-\log_2(c)$$

END OF SECTION A SUGGESTED ANSWERS

SECTION B

Question 1

a. $f: R \to R, \quad f(x) = x^4 - 4x^3 + 3$

$m(x) = f'(x) = 4x^2(x-3) = 0$

for turning points

$x = 0, \ x = 3, \quad f(3) = -24$

$(3, -24)$ is an absolute minimum turning point A1

b. $m'(x) = 12x^2 - 24x$

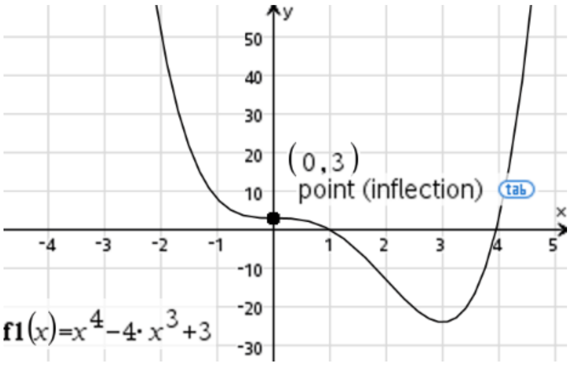
$m'(x) = 12x(x-2) = 0$ for inflection points

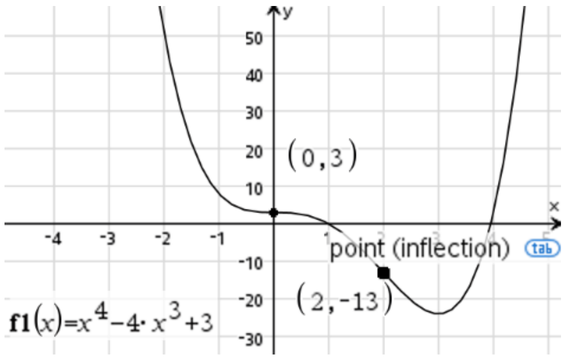
$x = 0, 2$

$f(0) = 3, \quad f(2) = -13$

$(0, 3)$ is a stationary point of inflection

$(2, -13)$ is a point of inflexion A1





c. at $x = 2 \quad f(2) = -13, \ f'(2) = -16$

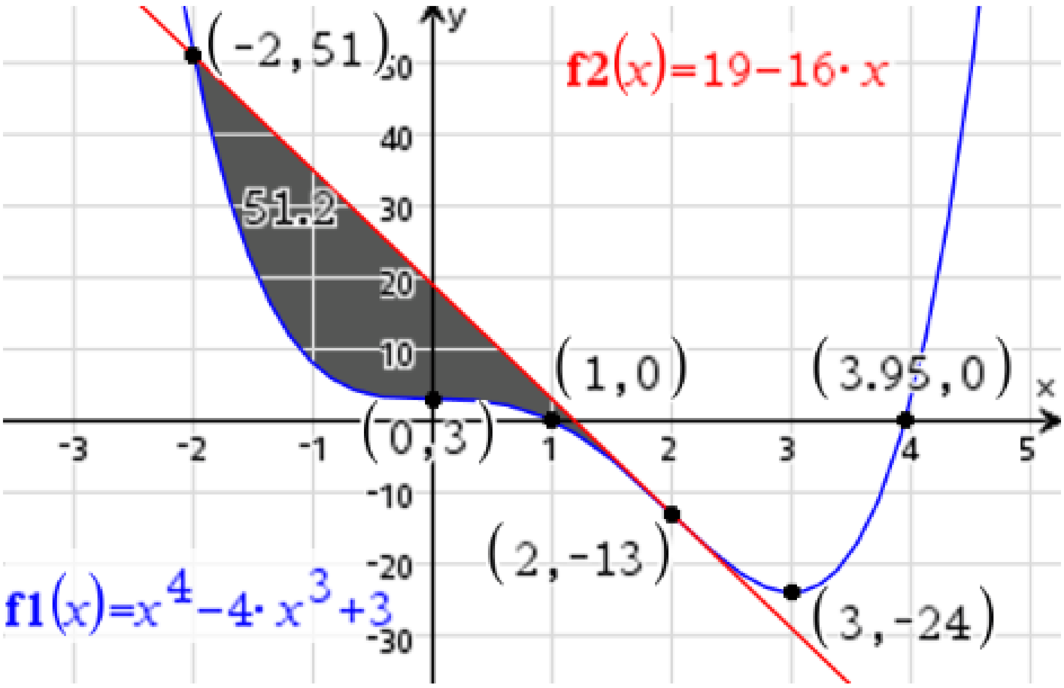
the tangent line at $x = 2$ is

$y + 13 = -16(x-2) = -16x + 32$

$y = g(x) = -16x + 19$ A1

note the curve crosses the tangent at the point of inflection.

d. G2



e. $g(x)-f(x)$

$=(-16x+19)-(x^4-4x^3+3)$

$=-x^4+4x^3-16x+16$ M1

$=-(x+2)(x-2)^3=(x+2)(2-x)^3$

$g(x)=f(x),\ \Rightarrow x=\pm 2$

i. the area is $A=\int_{-b}^{b}(g(x)-f(x))\,dx$

$A=\int_{-2}^{2}(x+2)(2-x)^3\,dx$ A1

$b=2,\quad n=3$

ii. $A=\dfrac{256}{5}=51\dfrac{1}{5}=51.2$ A1

f. solving $\dfrac{f(c)-f(1)}{c-1}=-12,\ c>1$ gives $c=\sqrt{3}$ or $c=3$ A1

g. $h:R\to R,\quad h(x)=f(x)+k$, need to translate the graph up by 24 or more units,

so that for the graph to not cross the x-axis, require $k>24$ or $k\in(24,\infty)$ A1

Define $f1(x)=x^4-4\cdot x^3+3$	*Done*
$\text{factor}(f1(x))$	$(x-1)\cdot(x^3-3\cdot x^2-3\cdot x-3)$
$\text{solve}(f1(x)=0,x)$	$x=1.00000$ or $x=3.95137$
$\text{solve}\left(\frac{d}{dx}(f1(x))=0,x\right)$	$x=0$ or $x=3$
$f1(3)$	-24
$f1(2)$	-13
$\text{tangentLine}(f1(x),x,2)$	$19-16\cdot x$
Define $f2(x)=19-16\cdot x$	*Done*
$\text{solve}(f1(x)=f2(x),x)$	$x=-2$ or $x=2$
$f2(x)-f1(x)$	$-x^4+4\cdot x^3-16\cdot x+16$
$\text{factor}(f2(x)-f1(x))$	$-(x-2)^3\cdot(x+2)$
$\int_{-2}^{2}\left(-(x-2)^3\cdot(x+2)\right)dx$	51.20000
$\text{solve}\left(\frac{f1(c)-f1(1)}{c-1}=-12,c\right) \mid c>1$	$c=\sqrt{3}$ or $c=3$

Question 2 $f: R \to R,\quad f(x) = e^{-x^2}$

a.i. $A(a) = 2af(a) = 2ae^{-a^2}$

$\frac{dA}{da} = \left(2 - 4a^2\right)e^{-a^2} = 0$ for maximum area $a = \frac{\sqrt{2}}{2}$ M1

ii. $A_{\max} = A\left(\frac{\sqrt{2}}{2}\right) = \sqrt{\frac{2}{e}}$ A1

iii. the inflexion points are $(\pm 0.7071, 0.6065)$ $a = \frac{\sqrt{2}}{2} \approx 0.7071$

yes Jenny's assertion is correct. A1

b.i. $s(a) = \sqrt{a^2 + \left(f(a)\right)^2} = \sqrt{a^2 + e^{-2a^2}}$

$\frac{ds}{da} = 0$ for minimum area $a = \frac{1}{2}\sqrt{\log_e(4)}$ A1

ii. $s_{\min} = s\left(\frac{1}{2}\sqrt{\log_e(4)}\right) = \frac{1}{2}\sqrt{\log_e(4) + 2}$ A1

c. $f(x) = e^{-x^2} \quad \to \quad f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2} = \frac{1}{\sigma\sqrt{2\pi}} e^{-\left(\frac{x-\mu}{\sqrt{2}\sigma}\right)^2}$ A1

$x = \frac{x' - \mu}{\sqrt{2}\sigma},\quad x' = \sqrt{2}\sigma x + \mu,\quad \mu > 0$ A2

- dilate by a factor of $\frac{1}{\sigma\sqrt{2\pi}}$ parallel to the *y*-axis (or away from the *x*-axis)
- dilate by a factor of $\sqrt{2}\sigma$ parallel to the *x*-axis (or away from the *y*-axis)
- translate by a factor of μ to the right parallel to the *x*-axis (or away from the *y*-axis)

Define $f1(x)=e^{-x^2}$	Done
Define $r(a)=2\cdot a\cdot f1(a)$	Done
$\frac{d}{da}(r(a))$	$(2-4\cdot a^2)\cdot e^{-a^2}$
solve$\left(\frac{d}{da}(r(a))=0,a\right)\mid a>0$	$a=\frac{\sqrt{2}}{2}$
$r\left(\frac{\sqrt{2}}{2}\right)$	$e^{\frac{-1}{2}}\cdot\sqrt{2}$
$\frac{d^2}{dx^2}(f1(x))$	$(4\cdot x^2-2)\cdot e^{-x^2}$
solve$\left(\frac{d^2}{dx^2}(f1(x))=0,x\right)$	$x=\frac{-\sqrt{2}}{2}$ or $x=\frac{\sqrt{2}}{2}$

Define $s(a)=\sqrt{a^2+(f1(a))^2}$	Done
solve$\left(\frac{d}{da}(s(a))=0,a\right)\mid a>0$	$a=\frac{\sqrt{2\cdot\ln(2)}}{2}$
$s\left(\frac{\sqrt{2\cdot\ln(2)}}{2}\right)$	$\frac{\sqrt{2\cdot(\ln(2)+1)}}{2}$

Question 3

a.i. $P \stackrel{d}{=} Bi\left(n=50,\ p=0.46\right)$

binomCdf(50,0.46,26,50) 0.238643

$\Pr\left(P>25\right)$

$=\Pr\left(26 \le P \le 50\right)=0.2386$ A1

ii. $E \stackrel{d}{=} Bi\left(n=?,\ p=0.07\right)$

solve$\left((0.93)^{n}+n\cdot(0.03)^{n-1}\cdot 0.07=0.31,n\right)$ $n=16.1385$

binomCdf$(n,0.07,2,n)|n=15$ 0.2832

binomCdf$(n,0.07,2,n)|n=16$ 0.3098

invBinomN(0.7,0.07,1,1) $\begin{bmatrix} 15 & 0.7168 \\ 16 & 0.6902 \end{bmatrix}$

$\Pr\left(E \ge 2\right) \ge 0.3$

$1-\Pr\left(E \le 1\right) \le 0.7$

$1-\left(\Pr\left(E=0\right)+\Pr\left(E=1\right)\right) \le 0.7$

$\Pr\left(E=0\right)+\Pr\left(E=1\right) \ge 0.3$

$0.93^{n}+n \times 0.93^{n-1} \times 0.07 \ge 0.3$

$n=16$ A1

b. $\Pr\left(EH \mid NB\right)=\dfrac{\Pr\left(EH \cap NB\right)}{\Pr\left(NB\right)}=\dfrac{23}{177}$

$=\dfrac{0.23\left(1-b\right)}{0.23\left(1-b\right)+0.77\times 0.6}=\dfrac{23}{177}$ M1

$b=0.7,\quad 70\%$ A1

c.i. $B \stackrel{d}{=} N\left(96,8^{2}\right)$ time in months

$\Pr\left(B>120 \mid B \ge 108\right)$ M1

$=\dfrac{\Pr\left(B>120\right)}{\Pr\left(B \ge 108\right)}=\dfrac{0.00135}{0.0668}$

$\dfrac{\text{normCdf}(120,\infty,96,8)}{\text{normCdf}(108,\infty,96,8)}$ 0.0202

$=0.0202$ A1

ii. $\Pr\left(B>t\right)=0.8$

$\dfrac{t-96}{8}=0.8416$

$\dfrac{\text{invNorm}(0.8,96,8)}{12}$ 8.5611

$t=102.73$ months

8.56 years A1

iii. $S \stackrel{d}{=} Bi\left(n=10,\ p=0.0668\right)$ A1

p:=normCdf(108,∞,96,8) 0.0668

binomCdf(10,p,3,10) 0.0251

$\Pr\left(S>2\right)$

$=\Pr\left(3 \le S \le 10\right)=0.0251$ A1

d. White: $\hat{p}_W = 0.34,\quad 95\%,\quad z = 1.96$

$$(1)\ CL_W = 0.34 - 1.96\sqrt{\frac{0.34(1-0.34)}{n_W}}$$

Black: $\hat{p}_B = 0.21,\quad 99\%,\quad z = 2.576$ M1

$$(2)\ CU_B = 0.21 + 2.576\sqrt{\frac{0.21(1-0.21)}{n_B}}$$ A1

solving $(1)=(2)\quad CL_W = CU_B$ with $n_B = 3n_W$

gives $n_W = 139$ A1

$z95:=\text{invNorm}(0.975,0,1)$ 1.9600

$z99:=\text{invNorm}(0.995,0,1)$ 2.5758

$clw:=0.34-z95\cdot\sqrt{\frac{0.34\cdot(1-0.34)}{nw}}$ $0.3400-0.9285\cdot\sqrt{\frac{1}{nw}}$

$clu:=0.21+z99\cdot\sqrt{\frac{0.21\cdot(1-0.21)}{nb}}$ $1.0492\cdot\sqrt{\frac{1}{nb}}+0.2100$

$\text{solve}(clw=clu,nw)|nb=3\cdot nw$ $nw=139.2732$

e. $T \overset{d}{=} N(\mu = ?, \sigma^2 = ?)$ time in years

$\Pr(T > 7) = 0.86$

$\Pr(T < 7) = 0.14$

$$(1)\quad \frac{7-\mu}{\sigma} = -1.0803$$ M1

$\text{invNorm}(0.14,0,1)$ -1.0803

$\text{invNorm}(0.05,0,1)$ -1.6449

$\Pr(T < 5) = 0.05$

$$(2)\quad \frac{5-\mu}{\sigma} = -1.6449$$

$\text{solve}\left(\frac{7-m}{s}=-1.0803 \text{ and } \frac{5-m}{s}=-1.6449,\{m,\right.$ ▸

$s=3.5423 \text{ and } m=10.8268$

solving $(1),(2)\quad \mu = 10.8,\quad \sigma = 3.5$ A1

f.
$$f(t) = \begin{cases} b(2t-1) & \text{for } \frac{1}{2} \le t \le 1 \\ \dfrac{b}{\left(t-\frac{1}{2}\right)^2} & \text{for } 1 < t \le 4 \\ 0 & \text{elsewhere} \end{cases}$$

since it is a probability density function $\int_{0.5}^{4} f(t)\,dt = 1$ solving gives $b = \frac{28}{55}$

$E(T) = \int_{0.5}^{4} t\, f(t)\,dt = 1.5331$

$E(T^2) = \int_{0.5}^{4} t^2\, f(t)\,dt = 2.8263$

$sd(T) = \sqrt{E(T^2) - (E(T))^2} = 0.6899$ M1

$E(T) + 2sd(T) = 2.9129$

$E(T) - 2sd(T) = 0.1533 < 0.5$

$\Pr(0.5 \le T \le E(T) + 2sd(T))$

$= \Pr(0.5 \le T \le 2.9129)$

$= \int_{0.5}^{2.9129} f(t)\,dt = 0.9345$ A1

Define $f(t) = \begin{cases} b\cdot(2\cdot t - 1), & \frac{1}{2} \le t < 1 \\ \frac{b}{\left(t - \frac{1}{2}\right)^2}, & 1 \le t \le 4 \end{cases}$ Done

solve$\left(\int_{\frac{1}{2}}^{4} f(t)\,dt = 1, b\right)$ $b = \frac{28}{55}$

Define $f(t) = \begin{cases} b\cdot(2\cdot t - 1), & \frac{1}{2} \le t < 1 \\ \frac{b}{\left(t - \frac{1}{2}\right)^2}, & 1 \le t \le 4 \end{cases} \Big| b = \frac{28}{55}$ Done

$ex := \int_{\frac{1}{2}}^{4} (t\cdot f(t))\,dt$ 1.5331

$ex2 := \int_{\frac{1}{2}}^{4} (t^2\cdot f(t))\,dt$ 2.8263

$sdx := \sqrt{ex2 - ex^2}$ 0.6899

$ex + 2\cdot sdx$ 2.9129

$ex - 2\cdot sdx$ 0.1533

$\int_{\frac{1}{2}}^{2.91285} f(t)\,dt$ 0.9345

Question 4

a. $f:[-\pi,\pi]\to R,\quad f(x)=x^2\cos(x)$

$f(-x)=(-x)^2\cos(-x)$

$\quad =x^2\cos(x)=f(x)$ A1

so f is an even function and the graph of $y=f(x)$

is symmetrical about the y-axis. A1

b. $f'(x)=2x\cos(x)-x^2\sin(x)=x\left(2\cos(x)-x\sin(x)\right)$

for non-zero turning points $g(x)=2\cos(x)-x\sin(x)=0$

$g'(x)=-3\sin(x)-x\cos(x),\quad x_0=0.75$

$x_1=x_0-\dfrac{g(x_0)}{g'(x_0)}=1.117$ M1

$x_2=x_1-\dfrac{g(x_1)}{g'(x_1)}=1.077$

A1

x_0	0.75
x_1	1.117
x_2	1.077

Define $f1(x)=x^2\cdot\cos(x)$	*Done*
Define $m(x)=\frac{d}{dx}(f1(x))$	*Done*
$m(x)$	$2\cdot x\cdot\cos(x)-x^2\cdot\sin(x)$
Define $g(x)=\frac{m(x)}{x}$	*Done*
$g(x)$	$2\cdot\cos(x)-x\cdot\sin(x)$

Define $dg(x)=\frac{d}{dx}(g(x))$	*Done*
$dg(x)$	$-x\cdot\cos(x)-3\cdot\sin(x)$
$0.75-\frac{g(0.75)}{dg(0.75)}$	1.117
$1.117-\frac{g(1.117)}{dg(1.117)}$	1.077

c.i. $y-a^2\cos(a)=\left(2a\cos(a)-a^2\sin(a)\right)(x-a)$

$y=\left(2a\cos(a)-a^2\sin(a)\right)x-a^2\left(\cos(a)-a\sin(a)\right)$ A1

ii. solving $y=0$ when $x=\pi$ and $0<a<\pi$ gives $a=1.151$, and A1

$y=0.852-0.271x$ A1

tangentLine$(f1(x),x,a)$

$$2.000\cdot a\cdot(\cos(a)-0.500\cdot a\cdot\sin(a))\cdot x-a^2\cdot(\cos(a)-a\cdot\sin(a))$$

solve$\left(a\cdot(2\cdot\cos(a)-a\cdot\sin(a))\cdot x-a^2\cdot(\cos(a)-a\cdot\sin(a))=0,a\right)|x=$

$$(a-2\cdot\pi)\cdot\cos(a)-a\cdot(a-\pi)\cdot\sin(a)=0 \text{ and } 0<a<\pi$$

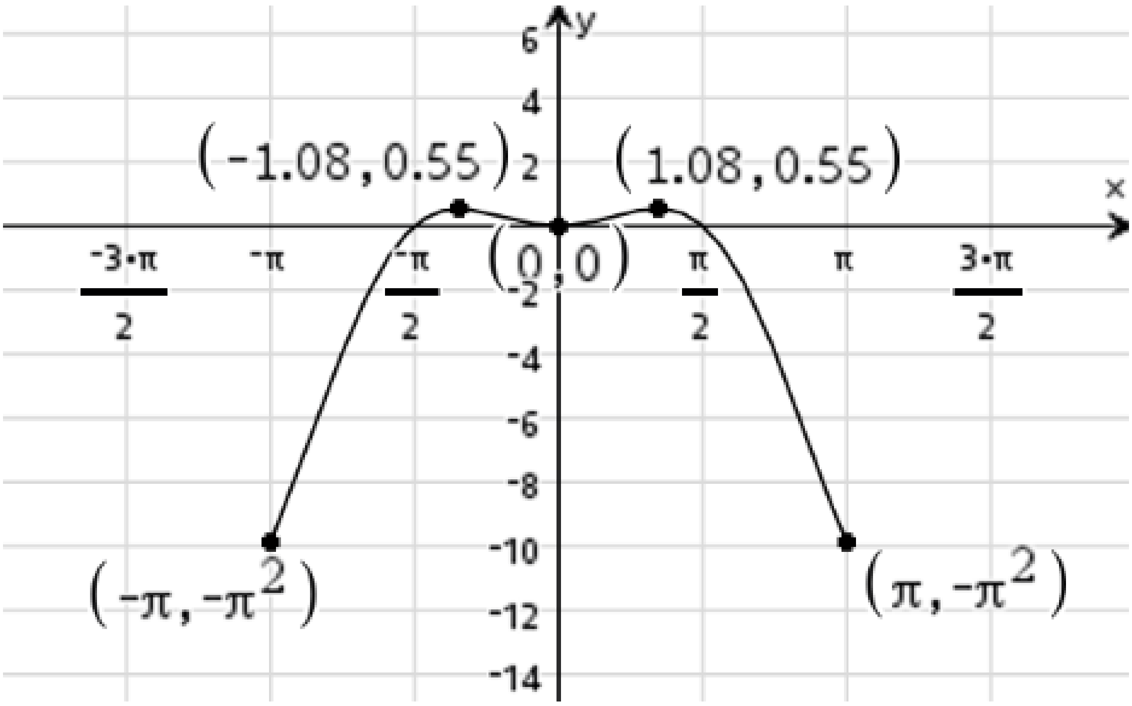
$a\cdot(2\cdot\cos(a)-a\cdot\sin(a))\cdot x-a^2\cdot(\cos(a)-a\cdot\sin(a))|a=1.1509284$

$$0.852-0.271\cdot x$$

d. endpoints $\left(\pm\pi,-\pi^2\right)$

local minimum turning point $(0,0)$ A1

absolute maximum turning points $(\pm1.08,0.55)$ G2



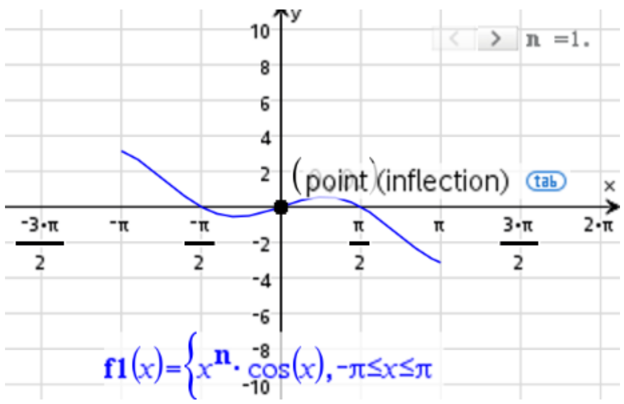
e. f is strictly increasing for $x\in[-3.14,-1.08]$ or $x\in[0,1.08]$ A1

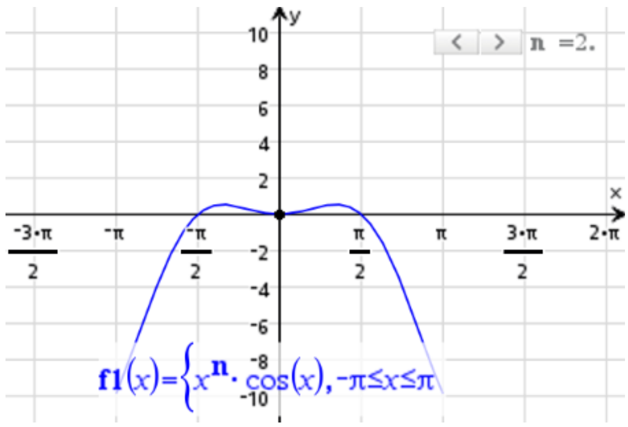
f. $\bar{f}=\dfrac{1}{\pi-(-\pi)}\int_{-\pi}^{\pi}x^2\cos(x)\,dx=-2$ A1

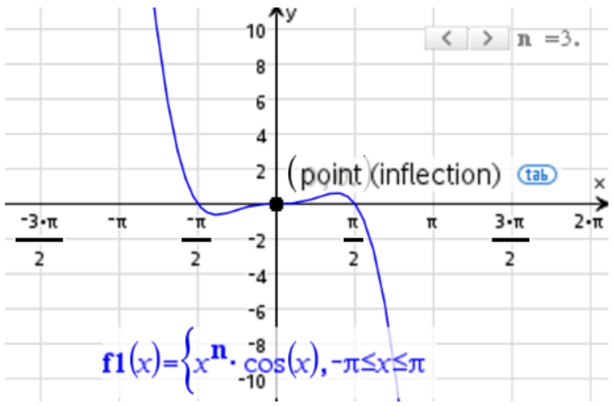
$$\frac{1}{\pi--\pi}\cdot\int_{-\pi}^{\pi}f1(x)\,dx \qquad -2$$

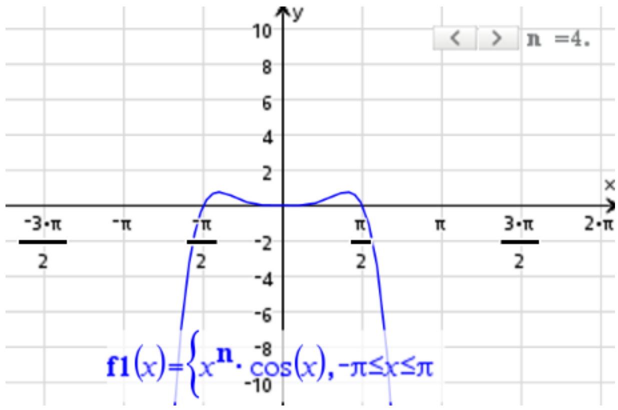
g. $f_n : [-\pi, \pi] \to R, \quad f_n(x) = x^n \cos(x), \quad n \in N.$ A2

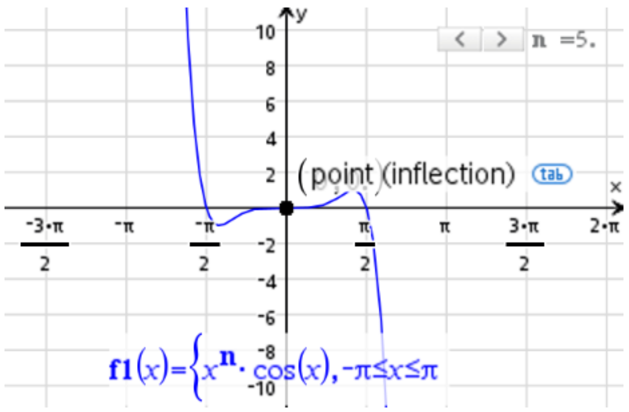
values of n	The graph of $y = f_n(x)$ at the origin has
$n = 1$	a point of inflection
n even, 2,4,6,…. $n = 2k, k \in Z^+$	a local minimum turning point
n odd, 3,5,7,…. $n = 2k+1, k \in Z^+$	a stationary point of inflection











Question 5

a. $f:\left[\frac{3}{2},\infty\right)\to R\ ,\ \ f(x)=\sqrt{4x^2-9}$

$f:\quad y=\sqrt{4x^2-9}$

$f^{-1}:\ x=\sqrt{4y^2-9}\ ,\ \ x^2=4y^2-9,\ \ y^2=\dfrac{x^2+9}{4}$

domain $f\ =$ range of $f^{-1}=\left[\frac{3}{2},\infty\right)$

domain $f^{-1}=$ range of $f=[0,\infty)$

$f^{-1}:[0,\infty)\to R\ ,\ \ f^{-1}(x)=\dfrac{\sqrt{x^2+9}}{2}$ A1

b. solving $f(x)=f^{-1}(x)\quad\Rightarrow x=\sqrt{3}$

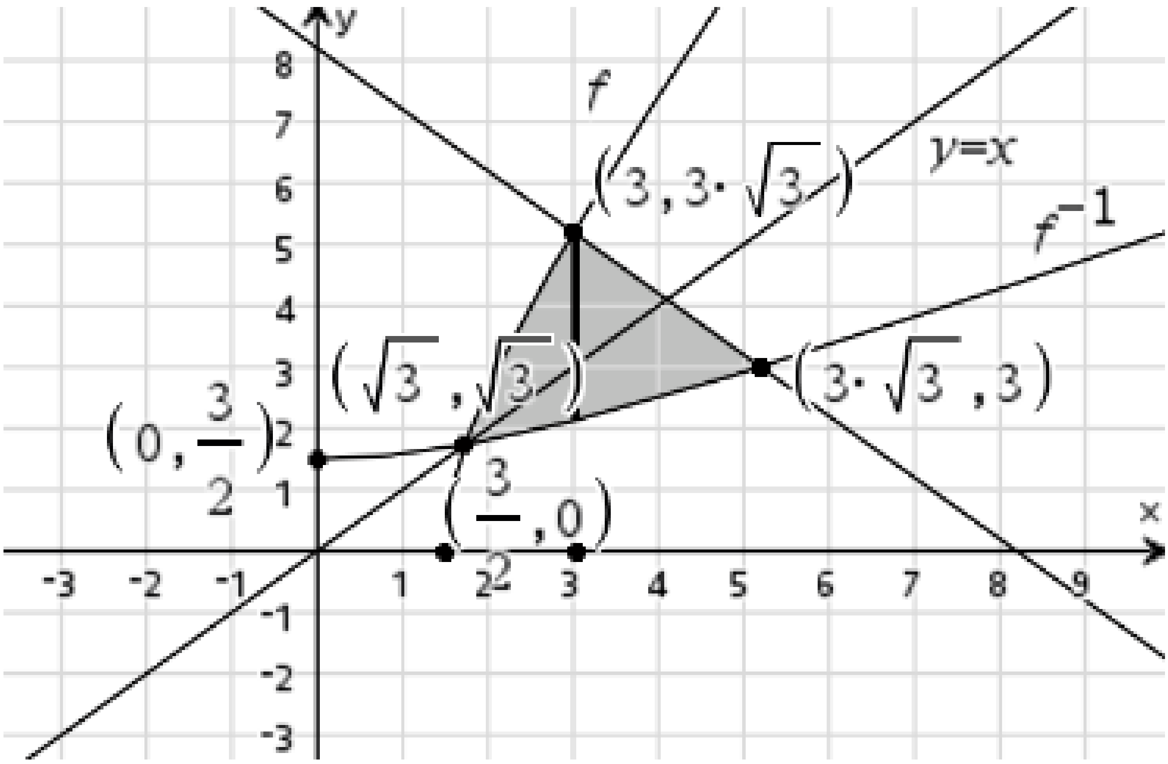
$P\left(\sqrt{3},\sqrt{3}\right)$ A1

Define $f1(x)=\sqrt{4\cdot x^2-9}$ *Done*

Define $f2(x)=\dfrac{\sqrt{x^2+9}}{2}$ *Done*

solve$(f1(x)=f2(x),x)|x>0$ $x=\sqrt{3}$

c. G2



d.i. The line $y=-x+3\left(\sqrt{3}+1\right)$ intersects the graph of $f(x)=\sqrt{4x^2-9}$ at the point $\left(3,3\sqrt{3}\right)$

and the line $y=-x+3\left(\sqrt{3}+1\right)$ intersects the graph of $f^{-1}(x)=\dfrac{\sqrt{x^2+9}}{2}$ at the point $\left(3\sqrt{3},3\right)$.

The area is $A=\int_{\sqrt{3}}^{3}\left(f(x)-f^{-1}(x)\right)dx+\int_{3}^{3\sqrt{3}}\left(-x+3\left(\sqrt{3}+1\right)-f^{-1}(x)\right)dx$ M1

$$A=\int_{\sqrt{3}}^{3}\left(\sqrt{4x^2-9}-\frac{\sqrt{x^2+9}}{2}\right)dx+\int_{3}^{3\sqrt{3}}\left(-x+3\left(\sqrt{3}+1\right)-\frac{\sqrt{x^2+9}}{2}\right)dx$$ A1

$$\int_{\sqrt{3}}^{3}(f1(x)-f2(x))\,dx+\int_{3}^{3\cdot\sqrt{3}}(f4(x)-f2(x))\,dx \qquad 5.5456$$

ii. $A=5.546$ A1

e. $f(x)=\sqrt{4x^2-9}$

$f'(x)=\dfrac{4x}{\sqrt{4x^2-9}}$

$f'\left(\sqrt{3}\right)=4=\tan(\theta_1)$

$f^{-1}(x)=\dfrac{\sqrt{x^2+9}}{2}$

$\dfrac{d}{dx}\left(f^{-1}(x)\right)=\dfrac{x}{\sqrt{x^2+9}}$ A1

$\dfrac{d}{dx}\left(f^{-1}(x)\right)\Big|_{x=\sqrt{3}}=\dfrac{1}{4}=\tan(\theta_2)$

$\theta_1-\theta_2=\tan^{-1}(4)-\tan^{-1}\left(\dfrac{1}{4}\right)=61.9^0$ A1

$$\frac{d}{dx}(f1(x))|x=\sqrt{3} \qquad 4$$

$$\frac{d}{dx}(f2(x))|x=\sqrt{3} \qquad \frac{1}{4}$$

$$\tan^{-1}(4)-\tan^{-1}\left(\frac{1}{4}\right) \qquad 61.9275$$

f. $f(x)=\sqrt{kx^2-9} \quad x \in \left[\frac{3}{\sqrt{k}}, \infty\right)$

domain $f = \left[\frac{3}{\sqrt{k}}, \infty\right)$ since it is a one-one increasing function, so $k>0$.

$f^{-1}(x)=\sqrt{\frac{x^2+9}{k}}$

Define $f(x)=\sqrt{k\cdot x^2-9}$ — Done

Define $g(x)=\frac{\sqrt{x^2+9}}{\sqrt{k}}$ — Done

solve$(f(x)=g(x),x)$

$x=\frac{3}{\sqrt{k-1}}$ and $\frac{1}{k-1}\ge 0$ or $x=\frac{-3}{\sqrt{k-1}}$ and $\frac{1}{k-}$ ▸

The graphs do not intersect when $0<k\le 1$ or $k\in(0,1]$ A1

g. $f(x)=\sqrt{kx^2-9}$, $\quad f'(x)=\frac{kx}{\sqrt{kx^2-9}}$, $\quad f'(c)=\frac{kc}{\sqrt{kc^2-9}}=\tan(\theta_1)$

$f^{-1}(x)=\sqrt{\frac{x^2+9}{k}}$, $\quad \frac{d}{dx}\left(f^{-1}(x)\right)=\frac{x}{\sqrt{k(x^2+9)}}$, $\quad \frac{d}{dx}\left(f^{-1}(x)\right)\Big|_{x=c}=\frac{c}{\sqrt{k(c^2+9)}}=\tan(\theta_2)$

$f(c)=f^{-1}(c)$ A1

$\Rightarrow \; k=\frac{c^2+9}{c^2}, \quad c=\frac{3}{\sqrt{k-1}}$

$\theta_1-\theta_2=\tan^{-1}\left(\frac{12}{5}\right)=\tan^{-1}(5)-\tan^{-1}\left(\frac{1}{5}\right)$

solving $\frac{kc}{\sqrt{kc^2-9}}=5$ and $\frac{c}{\sqrt{k(c^2+9)}}=\frac{1}{5}$

with $c=\frac{3}{\sqrt{k-1}}$

gives $c=\frac{3}{2}$

$k=5$

$\tan^{-1}(5)-\tan^{-1}\left(\frac{1}{5}\right)$ — 67.3801

$\tan^{-1}\left(\frac{12}{5}\right)$ — 67.3801

$eq1:=\frac{c\cdot k}{\sqrt{c^2\cdot k-9}}=5$ — $\frac{c\cdot k}{\sqrt{c^2\cdot k-9}}=5$

$eq2:=\frac{c}{\sqrt{(c^2+9)\cdot k}}=\frac{1}{5}$ — $\frac{c}{\sqrt{(c^2+9)\cdot k}}=\frac{1}{5}$

solve$(eq1$ and $eq2,k)|c=\frac{3}{\sqrt{k-1}}$ — $k=5$ A1

END OF SECTION B SUGGESTED ANSWERS

End of detailed answers for the
2024 Kilbaha VCE Mathematical Methods Trial Examination 2

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