

**Year 2006**

**VCE**

**Specialist Mathematics**

**Examination 2**

**Suggested Solutions**



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**Specialist Mathematics Examination 2 Solutions 2006****SECTION 1****Question 1                      Answer C**

The hyperbola  $\frac{(x-2)^2}{9} - \frac{(y-1)^2}{4} = 1$  has asymptotes when the right hand side is zero,

$$\frac{(x-2)^2}{9} - \frac{(y-1)^2}{4} = 0 \quad \text{taking the square root of both sides} \quad \frac{(x-2)}{3} = \pm \frac{(y-1)}{2}$$

$$2(x-2) = \pm 3(y-1)$$

$$2x-4 = 3y-3 \qquad 2x-4 = -3y+3$$

$$2x-3y=1 \quad \text{and} \quad 2x+3y=7 \quad \text{as the equation of the asymptotes.}$$

**Question 2                      Answer E**

The function  $f(x) = \frac{1}{(x-4)(x+2)}$  has vertical asymptotes when the denominator is zero,

that is when  $(x-4)(x+2) = 0$  at  $x=4$  and  $x=-2$

now  $(x-4)(x+2) = x^2 - 2x - 8$  so  $f'(x) = 0$  when  $2x-2=0$  at  $x=1$

and  $f(1) = \frac{1}{-3 \times 3} = -\frac{1}{9}$ , there is a turning point at  $\left(1, -\frac{1}{9}\right)$

**Question 3                      Answer D**

$r(t) = (1+t)\underline{i} + (1-t)\underline{j}$  is the position vector, the parametric equations are

$$(1) \quad x = 1+t \quad (2) \quad y = 1-t \quad \text{adding (1)+(2) gives} \quad x+y=2 \quad \text{so} \quad y = -x+2$$

**Question 4                      Answer C**

Let  $z = a+bi$  where  $a, b \in R$  and  $a > b > 0$

now  $-i(a+bi) = i^3(a+bi)$  is a rotation of  $z$  by  $270^\circ$  anticlockwise from  $z$ ,

or a rotation  $90^\circ$  clockwise from  $z$ .

**Question 5**                      **Answer B**

$$z^5 = -a = a \operatorname{cis}(\pi) = a \operatorname{cis}(\pi + 2k\pi)$$

$$z = a^{\frac{1}{5}} \operatorname{cis}\left(\frac{\pi}{5} + \frac{2k\pi}{5}\right) \quad \text{when } k=0 \text{ one solution is } z = a^{\frac{1}{5}} \operatorname{cis}\left(\frac{\pi}{5}\right)$$

$$\text{when } k=2 \text{ another one of the five solutions is } z = a^{\frac{1}{5}} \operatorname{cis}(\pi) = -a^{\frac{1}{5}}$$

**Question 6**                      **Answer B**

The required region is the inside of a circle with centre  $c = a + 2i$  and radius  $r = 1$

$$|z - c| \leq r \text{ so } |z - (a + 2i)| \leq 1$$

**Question 7**                      **Answer E**

Checking each alternative

**A.** If  $z = x + iy$ ,  $\bar{z} = x - iy$ ,  $z + \bar{z} = 0$  so  $2x = 0$

**B.** If  $z = x + iy$   $\operatorname{Re}(z) = x$ ,  $\operatorname{Im}(z) = y$        $3\operatorname{Re}(z) = \operatorname{Im}(z) \Rightarrow 3x = y$

**C.**  $z = i\bar{z}$ ,  $x + iy = i(x - iy) = ix - i^2y = ix + y$

**D.**  $x - 2y = 0$

all of A.B.C. and D. pass through the origin,  $x = 0$   $y = 0$

**E.**  $x + y = 1$  does not pass through the origin.

**Question 8**                      **Answer A**

Given  $2x^3 - y^2 = 7$  using implicit differentiation  $\frac{d}{dx}(2x^3) - \frac{d}{dx}(y^2) = \frac{d}{dx}(7)$

$$6x^2 - 2y \frac{dy}{dx} = 0 \text{ so } \frac{dy}{dx} = \frac{6x^2}{2y} = \frac{3x^2}{y} \text{ now at the point where } y = -3, \quad 2x^3 - 9 = 7$$

$$2x^3 = 16, \quad x^3 = 8, \quad x = 2 \text{ the point is } (2, -3) \quad \left. \frac{dy}{dx} \right|_{(2, -3)} = \frac{3 \times 4}{-3} = -4$$

**Question 9**      **Answer C**

$$\int_a^b x(x^2+1)^5 dx \quad \text{let } u = x^2+1 \quad \frac{du}{dx} = 2x$$

change terminals when  $x = b$   $u = b^2+1$  and when  $x = a$   $u = a^2+1$

$$\int_a^b x(x^2+1)^5 dx = \frac{1}{2} \int_{a^2+1}^{b^2+1} u^5 du$$

**Question 10**      **Answer B**

$x$  kg has dissolved,  $8-x$  kg is undissolved,  $\frac{dx}{dt} = \frac{5}{100}(8-x) = \frac{8-x}{20}$  for  $0 < x < 8$

**Question 11**      **Answer C**

At  $x=0$  the gradient of the curves is zero, at the point  $\left(\frac{1}{2}, \frac{1}{2}\right)$  the gradient is negative,

and less than one, option C. is the only one which satisfies this.

**Question 12**      **Answer D**

The velocity  $v = \sin(2x)$  then  $\frac{dv}{dx} = 2\cos(2x)$  then acceleration

$$a = v \frac{dv}{dx} = 2\sin(2x)\cos(2x) = \sin(4x)$$

**Question 13**      **Answer E**

$$\underline{r}(t) = (2t-10)\underline{i} + 3\underline{j} \quad \underline{s}(t) = 2\underline{i} + (t-1)\underline{j} \text{ for } t \geq 0$$

checking each alternative

$$\underline{r}(1) = -8\underline{i} + 3\underline{j} \quad \underline{s}(1) = 2\underline{i}$$

$$\underline{r}(4) = -2\underline{i} + 3\underline{j} \quad \underline{s}(4) = 2\underline{i} + 3\underline{j}$$

$$\underline{r}(5) = \quad 3\underline{j} \quad \underline{s}(5) = 2\underline{i} - 4\underline{j}$$

$$\underline{r}(6) = 2\underline{i} + 3\underline{j} \quad \underline{s}(6) = 2\underline{i} + 5\underline{j}$$

so  $R$  and  $S$  are never in the same position.

**Question 14**      **Answer B**

$\underline{r}(t) = (3-t)\underline{i} - 6\sqrt{t}\underline{j} + 5\underline{k}$  differentiating the position vector with respect to  $t$  gives the velocity vector  $\underline{\dot{r}}(t) = -\underline{i} - \frac{3}{\sqrt{t}}\underline{j}$  at  $t=9$   $\underline{\dot{r}}(9) = -\underline{i} - \underline{j}$ , this is the direction of motion of the particle when  $t=9$

**Question 15**      **Answer D**

In the parallelogram  $\underline{a} + \underline{b} + \underline{c} + \underline{d} = \underline{0}$   
and  $\underline{b} = -\underline{d}$  and  $\underline{a} = -\underline{c}$  so  $\underline{a} + \underline{c} = \underline{0}$

**Question 16**      **Answer D**

Let  $\underline{a} = 5\underline{i} + \underline{j} - 2\underline{k}$  and  $\underline{b} = \frac{1}{\sqrt{29}}(2\underline{i} - 4\underline{j} + 3\underline{k})$

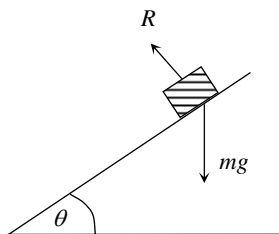
$$\underline{a} \cdot \underline{b} = 10 - 4 - 6 = 0 \quad \text{and} \quad |\underline{b}| = \frac{\sqrt{4+16+9}}{\sqrt{29}} = 1$$

Option **D.** is correct, the vectors in **A.**, **B.** and **C.** are not unit vectors and the vector in **E.** is not perpendicular to  $\underline{a}$

**Question 17**      **Answer B**

If  $\underline{u} = \underline{i} + \underline{j}$     $\underline{v} = \underline{i} + 2\underline{j} + 2\underline{k}$        $|\underline{u}| = \sqrt{2}$     $|\underline{v}| = \sqrt{1+4+4} = 3$     $\underline{u} \cdot \underline{v} = 1+2 = 3$

$$\cos(\theta) = \frac{\underline{u} \cdot \underline{v}}{|\underline{u}||\underline{v}|} = \frac{3}{3\sqrt{2}} = \frac{1}{\sqrt{2}} \quad \text{so} \quad \theta = 45^\circ$$

**Question 18**      **Answer A**

resolving perpendicular to the plane  $R - mg \cos(\theta) = 0$

so  $R = mg \cos(\theta)$     now  $m = 20 \text{ kg}$  ,  $\theta = 60^\circ$

$$R = 20g \cos(60^\circ) = 10g$$

**Question 19**      **Answer A**

A.  $12 \cos(30^\circ) = 10a$        $a = 1.04 \text{ m/s}^2$

B.  $10 \cos(10^\circ) = 10a$        $a = 0.98 \text{ m/s}^2$

C.  $10 = 10a$        $a = 1.0 \text{ m/s}^2$

D.  $10 \cos(20^\circ) = 10a$        $a = 0.94 \text{ m/s}^2$

E.  $12 \cos(45^\circ) = 10a$        $a = 0.85 \text{ m/s}^2$

the largest is **A**.

**Question 20**      **Answer D**

By Lami's Theorem

$$\frac{F_3}{\cos(150^\circ)} = \frac{F_2}{\cos(150^\circ)} = \frac{F_1}{\cos(60^\circ)}$$

$$F_3 = F_2 = \frac{F_1 \cos(150^\circ)}{\cos(60^\circ)} = \frac{\frac{1}{2}F_1}{\frac{\sqrt{3}}{2}} = \frac{F_1}{\sqrt{3}} = \frac{\sqrt{3}}{3}F_1$$

**Question 21**      **Answer A**

resolving perpendicular to the plane  $N - 8g \cos(30^\circ) = 0 \Rightarrow N = 8g \cos(30^\circ) = 4g\sqrt{3}$

resolving parallel to the plane  $F - 8g \sin(30^\circ) = 0 \Rightarrow F = 8g \sin(30^\circ) = 4g$

for equilibrium to be maintained  $F \leq \mu N$

$$4g \leq \mu 4g\sqrt{3}$$

$$\mu \geq \frac{1}{\sqrt{3}}$$

**Question 22**      **Answer E**

resolving around the 2 kg block, moving upward (1)  $T - 2g = 2a$

resolving around the 5kg block, moving downwards (2)  $5g - T = 5a$  adding (1)+(2)

gives  $3g = 7a$  so  $a = \frac{3g}{7}$

## SECTION 2

## Question 1

a.  $V = \pi \int_0^5 \frac{36x^2}{1+x^3} dx$

b. let  $u = 1 + x^3$   $\frac{du}{dx} = 3x^2$  when  $x = 5$   $u = 126$  and if  $x = 0$   $u = 1$

$$V = 12\pi \int_1^{126} \frac{1}{u} du$$

c.  $V = 12\pi [\log_e(u)]_1^{126} = 12\pi [\log_e(126) - \log_e(1)]$

$$V = 12\pi \log_e(126) = 182.32$$

$$V = 182 \text{ cm}^3$$

d. given  $\frac{dx}{dt} = 2 \text{ cm/sec}$  and  $\frac{dy}{dt} = \frac{6-3x^3}{(1+x^3)^{\frac{3}{2}}}$

then  $\frac{dy}{dt} = \frac{dy}{dx} \cdot \frac{dx}{dt} = \frac{2(6-3x^3)}{(1+x^3)^{\frac{3}{2}}}$

e.  $A = \pi y^2$  then  $\frac{dA}{dy} = 2\pi y = \frac{12\pi x}{\sqrt{1+x^3}}$

$$\frac{dA}{dt} = \frac{dA}{dy} \cdot \frac{dy}{dt} = \frac{24\pi x(6-3x^3)}{(1+x^3)^2} \text{ so } a = 24\pi, b = 1, c = 2$$

f.  $A$  is a maximum when  $\frac{dA}{dx} = 0$  or when  $\frac{dy}{dx} = 0$

so  $6 - 3x^3 = 0$  when  $3x^3 = 6$   $x^3 = 2$  so  $x = \sqrt[3]{2}$



## Question 2

$$\underline{a} = \overrightarrow{OA} = -\underline{i} - 4\underline{j} \quad \underline{b} = \overrightarrow{OB} = 2\underline{i} - 5\underline{j} \quad \underline{c} = \overrightarrow{OC} = 5\underline{i} - 4\underline{j} \quad \underline{d} = \overrightarrow{OD} = 2\underline{i} + 5\underline{j}$$

$$\text{a. } \overrightarrow{AC} = \underline{c} - \underline{a} = 6\underline{i} \quad \overrightarrow{BD} = \underline{d} - \underline{b} = 10\underline{j}$$

$$\overrightarrow{AC} \cdot \overrightarrow{BD} = 0 \text{ so } \overrightarrow{AC} \text{ is perpendicular to } \overrightarrow{BD}$$

$$\text{b. } \overrightarrow{DA} = \underline{a} - \underline{d} = -3\underline{i} - 9\underline{j} \quad |\overrightarrow{DA}| = \sqrt{9+81} = \sqrt{90}$$

$$\overrightarrow{DC} = \underline{c} - \underline{d} = 3\underline{i} - 9\underline{j} \quad |\overrightarrow{DC}| = \sqrt{9+81} = \sqrt{90}$$

$$\cos(\angle ADC) = \frac{\overrightarrow{DA} \cdot \overrightarrow{DC}}{|\overrightarrow{DA}| |\overrightarrow{DC}|} = \frac{-9+81}{90} = \frac{4}{5}$$

$$\text{c. } \overrightarrow{BA} = \underline{a} - \underline{b} = -3\underline{i} + \underline{j} \quad |\overrightarrow{BA}| = \sqrt{9+1} = \sqrt{10}$$

$$\overrightarrow{BC} = \underline{c} - \underline{b} = 3\underline{i} + \underline{j} \quad |\overrightarrow{BC}| = \sqrt{9+1} = \sqrt{10}$$

$$\cos(\angle ABC) = \frac{\overrightarrow{BA} \cdot \overrightarrow{BC}}{|\overrightarrow{BA}| |\overrightarrow{BC}|} = \frac{-9+1}{10} = -\frac{4}{5}$$

$$\text{so } \angle ADC + \angle ABC = \cos^{-1}\left(\frac{4}{5}\right) + \cos^{-1}\left(-\frac{4}{5}\right) = \cos^{-1}\left(\frac{4}{5}\right) + \left(180 - \cos^{-1}\left(\frac{4}{5}\right)\right) = 180^\circ$$

so the angles  $ADC$  and  $ABC$  add to  $180^\circ$ , they are supplementary angles.

$$\text{d. } \underline{p} = \overrightarrow{OP} = 2\underline{i}$$

$$\overrightarrow{PA} = \underline{a} - \underline{p} = -3\underline{i} - 4\underline{j} \quad |\overrightarrow{PA}| = \sqrt{9+16} = 5$$

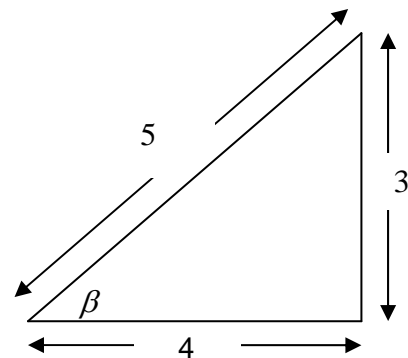
$$\overrightarrow{PC} = \underline{c} - \underline{p} = 3\underline{i} - 4\underline{j} \quad |\overrightarrow{PC}| = \sqrt{9+16} = 5$$

$$\cos(\angle APC) = \frac{\overrightarrow{PA} \cdot \overrightarrow{PC}}{|\overrightarrow{PA}| |\overrightarrow{PC}|} = \frac{-9+16}{25} = \frac{7}{25}$$

let  $\alpha = \angle APC$  and  $\beta = \angle ADC$  to show

$$\cos(\alpha) = \cos(2\beta)$$

$$\cos(\alpha) = \frac{7}{25} \quad \cos(2\beta) = \cos^2(\beta) - \sin^2(\beta) = \frac{16}{25} - \frac{9}{25} = \frac{7}{25} \quad \text{shown}$$



## Question 3

a. i.  $F = 105,600\text{N}$  ,  $m = 48,000\text{kg}$  using  $F = ma$

$$a = \frac{F}{m} = \frac{105,600}{48,000} = 2.2\text{ms}^{-2}$$

ii.  $u = 0$  ,  $a = 2.2\text{ms}^{-2}$  ,  $v = 70\text{ms}^{-1}$   $t = ?$  using  $v = u + at$

$$70 = 0 + 2.2t$$

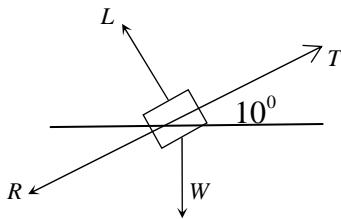
$$t = \frac{70}{2.2} = 31.8\text{s}$$

iii. using  $v^2 = u^2 + 2as$

$$70^2 = 0 + 2 \times 2.2 \times s$$

$$s = \frac{70^2}{2 \times 2.2} = 1113.64\text{m} = 1114\text{m}$$

b. i.



ii. resolving (1)  $T - R - W \sin(10^\circ) = 0$

$$(2) \quad L - W \cos(10^\circ) = 0$$

iii.  $L = W \cos(10^\circ) = 48,000 \times 9.8 \times \cos(10^\circ) = 463253.57 = 463,254\text{N}$

c. i.  $48,000a = -5v^2 - 500(80 - v) - 80,000$  all three forces oppose the motion of the plane.

ii.  $48,000a = -5v^2 - 40,000 + 500v - 80,000$

$$= -5v^2 + 500v - 120,000$$

$$a = v \frac{dv}{dx} = \frac{-5v^2 + 500v - 120,000}{48,000}$$

$$x = \int_{80}^{10} \frac{48,000 v dv}{-5v^2 + 500v - 120,000}$$

```

Plot1 Plot2 Plot3
Y1=48000X/(-5X^2
+500X-120000)
Y2=
Y3=
Y4=
Y5=
Y6=

```

```

fnInt(Y1,X,80,10)
)
1385

```

iii. 1385 m

**Question 4**

a.  $\frac{dy}{dt} = 1 - y$  inverting  $\frac{dt}{dy} = \frac{1}{1-y}$  integrating with respect to  $y$

$$t = \int \frac{1}{1-y} dy = -\log_e |(1-y)| + c \Rightarrow \log_e |1-y| = c - t \quad \text{where } c \text{ is the constant of integration}$$

b.  $\dot{\mathbf{z}}(t) = \frac{1}{y(t)} \dot{z} + (1-y(t)) \dot{j} = \dot{x}(t) \dot{i} + \dot{y}(t) \dot{j}$  so  $\frac{dx}{dt} = \frac{1}{y}$  now  $\frac{dy}{dx} = \frac{dy}{dt} \cdot \frac{dt}{dx} = \frac{\frac{dy}{dt}}{\frac{dx}{dt}} = y(1-y)$

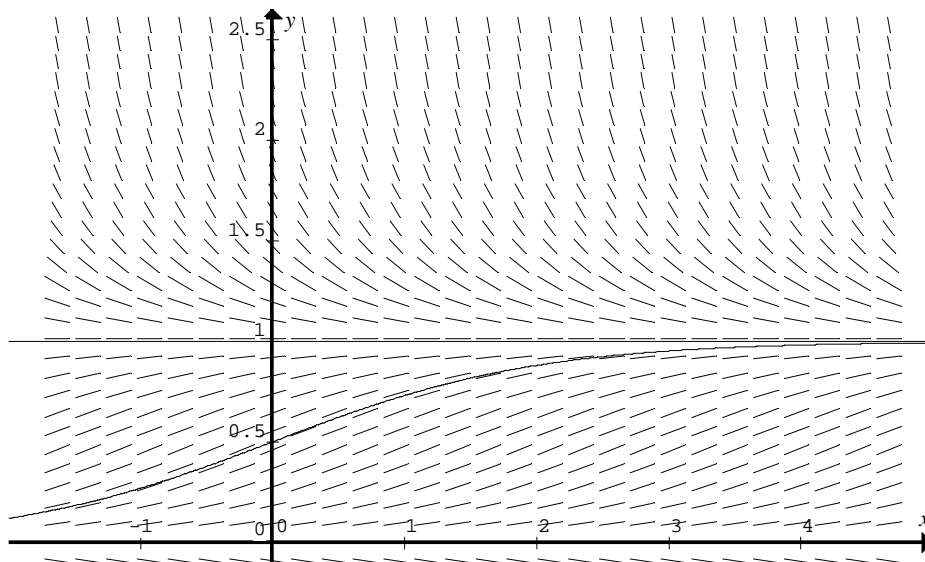
c. i. Given  $\frac{dy}{dx} = y(1-y)$  using implicit differentiation

$$\frac{d}{dx} \left( \frac{dy}{dx} \right) = \frac{d^2y}{dx^2} = \frac{d}{dx} [y(1-y)] = \frac{d}{dy} [(y-y^2)] \frac{dy}{dx} = (1-2y) \frac{dy}{dx} = (1-2y)y(1-y)$$

ii. For  $0 < y < 1$  if  $\frac{d^2y}{dx^2} = 0$  then  $y = \frac{1}{2}$  for an inflexion point.

if  $y < \frac{1}{2}$  then  $\frac{dy}{dx} > 0$  and if  $y > \frac{1}{2}$  then  $\frac{dy}{dx} < 0$  so  $\left(0, \frac{1}{2}\right)$  is an inflexion point

d.



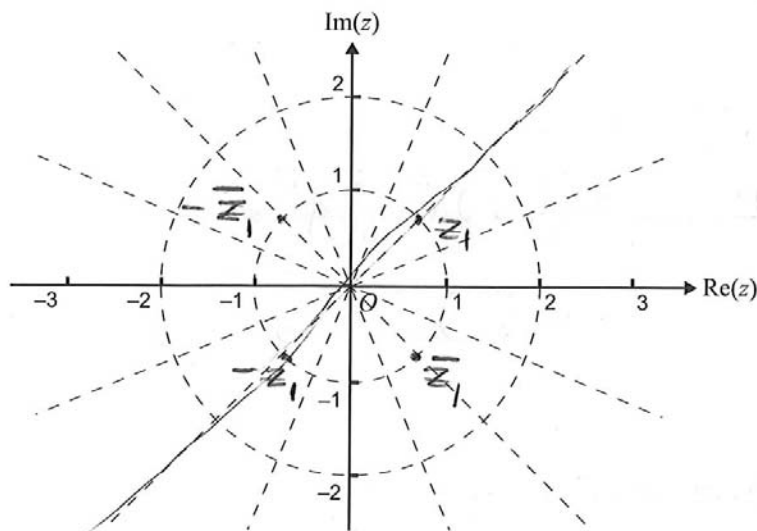
e.  $\frac{dy}{dx} = y(1-y) \quad y(0) = 2 \quad h = \frac{1}{4}$

$$y_1 = y_0 + hf(x_0, y_0) = 2 + \frac{1}{4}(2)(1-2) = \frac{3}{2}$$

$$y_2 = y_1 + hf(x_1, y_1) = \frac{3}{2} + \frac{1}{4} \left( \frac{3}{2} \right) \left( 1 - \frac{3}{2} \right) = \frac{21}{16}$$

## Question 5

a. i.



ii.  $\{ z : |z - \bar{z}_1| = |z + \bar{z}_1| \}$

b. Using  $\cos(2A) = 2\cos^2(A) - 1$  let  $A = \frac{\pi}{8}$

$$\cos\left(\frac{\pi}{4}\right) = \frac{\sqrt{2}}{2} = 2\cos^2\left(\frac{\pi}{8}\right) - 1$$

$$2\cos^2\left(\frac{\pi}{8}\right) = 1 + \frac{\sqrt{2}}{2} = \frac{2 + \sqrt{2}}{2}$$

$$\cos^2\left(\frac{\pi}{8}\right) = \frac{2 + \sqrt{2}}{4}$$

$$\cos\left(\frac{\pi}{8}\right) = \pm \frac{\sqrt{2 + \sqrt{2}}}{2} \text{ but } \cos\left(\frac{\pi}{8}\right) > 0 \text{ so we need to take the positive}$$

$$\cos\left(\frac{\pi}{8}\right) = \frac{\sqrt{2 + \sqrt{2}}}{2}$$

c.  $\sin^2\left(\frac{\pi}{8}\right) + \cos^2\left(\frac{\pi}{8}\right) = 1$

$$\sin^2\left(\frac{\pi}{8}\right) = 1 - \cos^2\left(\frac{\pi}{8}\right) = 1 - \frac{2 + \sqrt{2}}{4} = \frac{4 - (2 + \sqrt{2})}{4} = \frac{2 - \sqrt{2}}{4} \text{ and } \sin\left(\frac{\pi}{8}\right) > 0$$

$$\sin\left(\frac{\pi}{8}\right) = \frac{\sqrt{2 - \sqrt{2}}}{4}$$

$$\text{d. } \left( \frac{\sqrt{2+\sqrt{2}}}{2} + \frac{\sqrt{2-\sqrt{2}}}{2}i \right)^7 = \left[ \cos\left(\frac{\pi}{8}\right) + i\sin\left(\frac{\pi}{8}\right) \right]^7 = \text{cis}\left(\frac{7\pi}{8}\right)$$

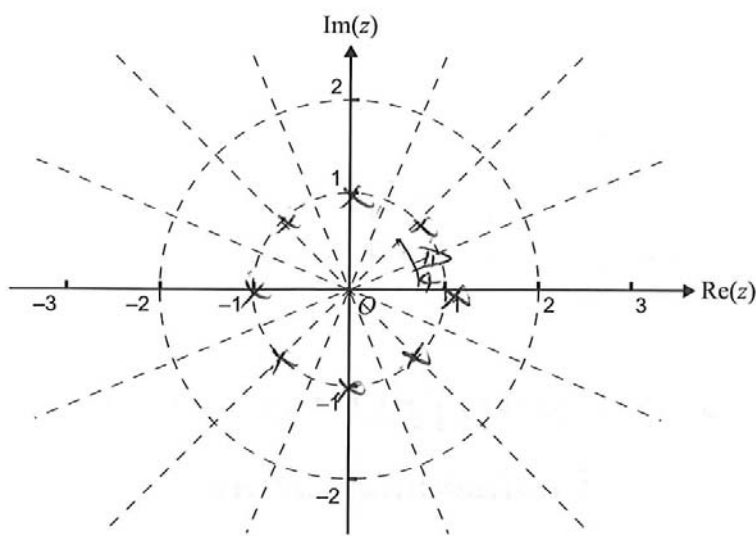
$$\text{e. } \text{if } \left( \frac{\sqrt{2+\sqrt{2}}}{2} + \frac{\sqrt{2-\sqrt{2}}}{2}i \right)^n \text{ is a real number}$$

$$= \left[ \text{cis}\left(\frac{\pi}{8}\right) \right]^n = \text{cis}\left(\frac{n\pi}{8}\right) = \pm 1 + 0i = \cos\left(\frac{n\pi}{8}\right) + i\sin\left(\frac{n\pi}{8}\right)$$

$$\text{so } \sin\left(\frac{n\pi}{8}\right) = 0 \quad \frac{n\pi}{8} = k\pi$$

$$n = 8k \text{ where } k \in J \text{ or } n = 0, \pm 8, \pm 16, \dots$$

- f. The roots of  $z^8 = 1$  are all on a circle of radius one, all the roots are equally separated by  $\frac{2\pi}{8} = 45^\circ$ , there are 8 roots.





# Mathematics 2007

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