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,

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

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

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

$2x-3y=1$ and $2x+3y=7$ 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**

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

(1) $x=1+t$ (2) $y=1-t$ adding $(1)+(2)$ gives $x+y=2$ so $y=-x+2$

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 $270°$ anticlockwise from *z*,

or a rotation $90°$ clockwise from *z*.

Question 5 **Answer B**

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

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

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

Question 6 **Answer B**

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

$|z - c| \le r$ so $|z - (a + 2i)| \le 1$

Question 7 **Answer E**

Checking each alternative

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

B. If $z = x + iy$ $\text{Re}(z) = x$, $\text{lm}(z) = y$ $3\text{Re}(z) = \text{lm}(z)$ $\Rightarrow$ $3x = y$

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

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

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

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

Question 9 **Answer C**

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

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

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

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**

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

checking each alternative

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

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

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

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

so R and S are never in the same position.

Question 14 **Answer B**

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

Question 15 **Answer D**

In the parallelogram $\underset{\sim}{a} + \underset{\sim}{b} + \underset{\sim}{c} + \underset{\sim}{d} = \underset{\sim}{0}$

and $\underset{\sim}{b} = -\underset{\sim}{d}$ and $\underset{\sim}{a} = -\underset{\sim}{c}$ so $\underset{\sim}{a} + \underset{\sim}{c} = \underset{\sim}{0}$

Question 16 **Answer D**

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

$\underset{\sim}{a}.\underset{\sim}{b} = 10 - 4 - 6 = 0$ and $\left|\underset{\sim}{b}\right| = \frac{\sqrt{4+16+9}}{\sqrt{29}} = 1$

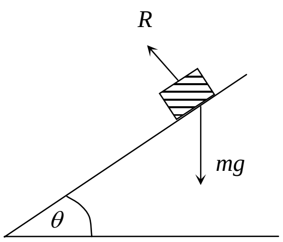
Option **D.** is correct, the vectors in **A. B.** and **C.** are not unit vectors and the vector in **E.** is not perpendicular to $\underset{\sim}{a}$

Question 17 **Answer B**

If $\underset{\sim}{u} = \underset{\sim}{i} + \underset{\sim}{j}$ $\underset{\sim}{v} = \underset{\sim}{i} + 2\underset{\sim}{j} + 2\underset{\sim}{k}$ $\left|\underset{\sim}{u}\right| = \sqrt{2}$ $\left|\underset{\sim}{v}\right| = \sqrt{1+4+4} = 3$ $\underset{\sim}{u}.\underset{\sim}{v} = 1 + 2 = 3$

$\cos(\theta) = \frac{\underset{\sim}{u}.\underset{\sim}{v}}{\left|\underset{\sim}{u}\right|\left|\underset{\sim}{v}\right|} = \frac{3}{3\sqrt{2}} = \frac{1}{\sqrt{2}}$ so $\theta = 45°$

Question 18 **Answer A**



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

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

$R = 20g\cos(60°) = 10g$

Question 19 **Answer A**

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

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

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

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

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

the largest is **A.**

Question 20 **Answer D**

By Lami's Theorem

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

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

Question 21 **Answer A**

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

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

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

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

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

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 $a = \dfrac{3g}{7}$

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

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

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

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

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

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

$\frac{dA}{dt} = \frac{dA}{dy} \cdot \frac{dy}{dt} = \frac{24\pi x\left(6-3x^3\right)}{\left(1+x^3\right)^2}$ 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

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

a. $\overrightarrow{AC} = \underset{\sim}{c} - \underset{\sim}{a} = 6\underset{\sim}{i}$ $\quad \overrightarrow{BD} = \underset{\sim}{a} - \underset{\sim}{b} = 10\underset{\sim}{j}$

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

b. $\overrightarrow{DA} = \underset{\sim}{a} - \underset{\sim}{d} = -3\underset{\sim}{i} - 9\underset{\sim}{j}$ $\quad \left|\overrightarrow{DA}\right| = \sqrt{9+81} = \sqrt{90}$

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

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

c. $\overrightarrow{BA} = \underset{\sim}{a} - \underset{\sim}{b} = -3\underset{\sim}{i} + \underset{\sim}{j}$ $\quad \left|\overrightarrow{BA}\right| = \sqrt{9+1} = \sqrt{10}$

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

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

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

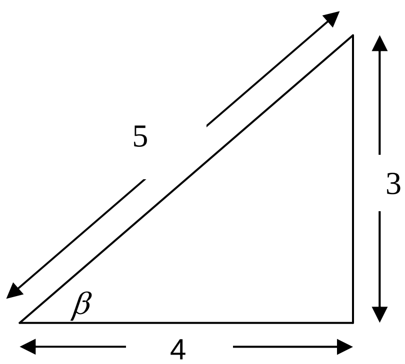
so the angles ADC and ABC add to 180°, they are supplementary angles.

d. $\underset{\sim}{p} = \overrightarrow{OP} = 2\underset{\sim}{i}$

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

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

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



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

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

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

Question 3

a. i. $F = 105,600N$, $m = 48,000\,\text{kg}$ 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 $v = u + at$

$$70 = 0 + 2.2t$$

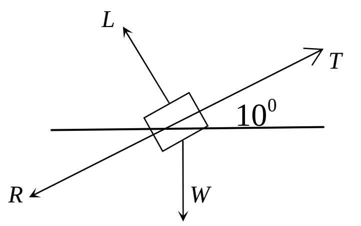
$$t = \frac{70}{2.2} = 31.8\,\text{s}$$

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

$$70^2 = 0 + 2 \times 2.2 \times 5$$

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

b. i.



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

(2) $L - W\cos(10°) = 0$

iii. $L = W\cos(10°) = 48,000 \times 9.8 \times \cos(10°) = 463253.57 = 463,254N$

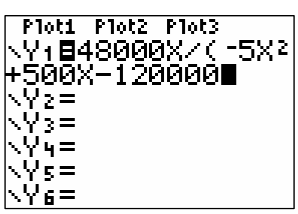
c. i. $48,000a = -5v^2 - 500(80 - v) - 80,000$ all three forces oppose the motion of the plane.

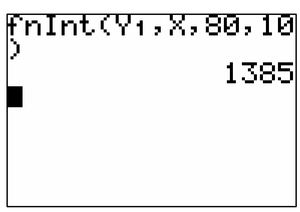
ii. $48,000a = -5v^2 - 40,000 + 500v - 80,000$

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

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

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





iii. 1385 m

Question 4

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

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

b. $\dot{\underset{\sim}{r}}(t)=\frac{1}{y(t)}\underset{\sim}{i}+\left(1-y(t)\right)\underset{\sim}{j}=\dot{x}(t)\underset{\sim}{i}+\dot{y}(t)\underset{\sim}{j}$ so $\frac{dx}{dt}=\frac{1}{y}$ now $\frac{dy}{dx}=\frac{dy}{dt}\cdot\frac{dt}{dx}=\frac{\frac{dy}{dt}}{\frac{dx}{dt}}=y(1-y)$

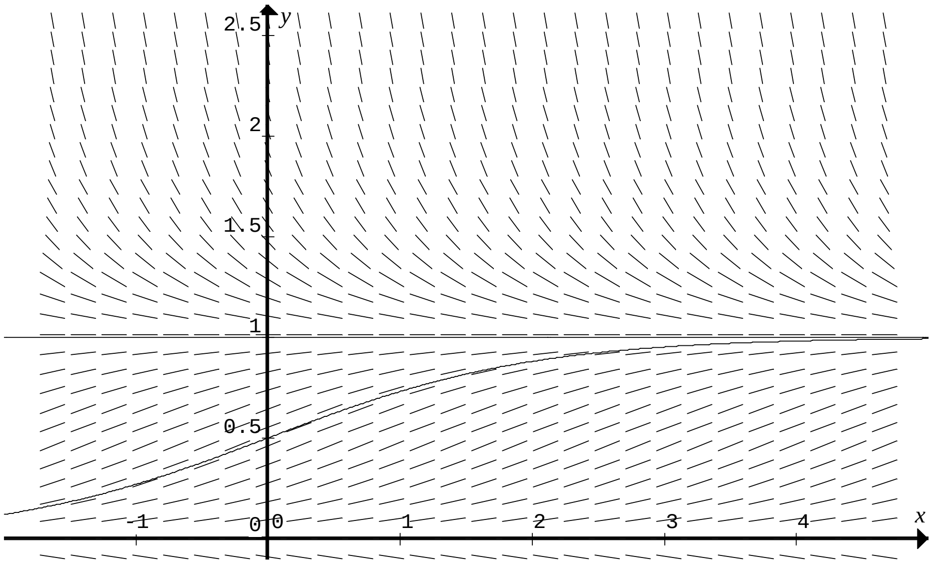
c. **i.** Given $\frac{dy}{dx}=y(1-y)$ using implicit differentiation

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

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.



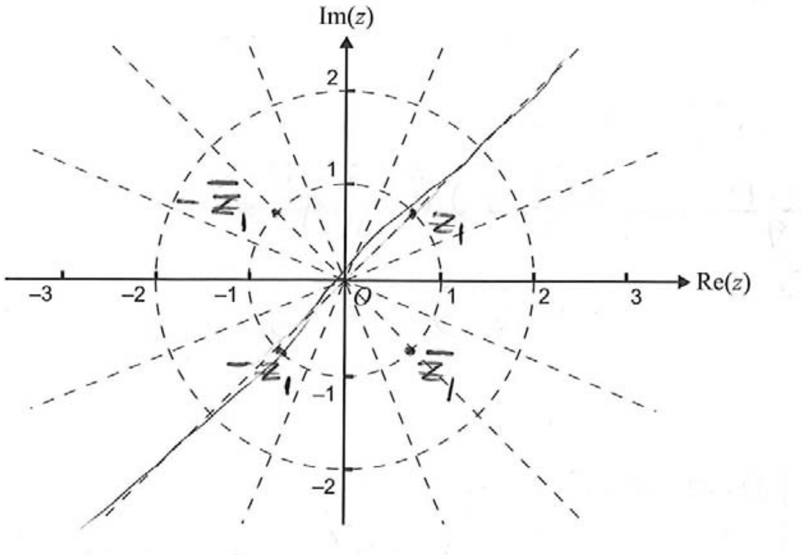
e. $\frac{dy}{dx}=y(1-y) \qquad y(0)=2 \qquad h=\frac{1}{4}$

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

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

Question 5

a. **i.**



ii. $\left\{ z : |z-\overline{z}_1| = |z+\overline{z}_1| \right\}$

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

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

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

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

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

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

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

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

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

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

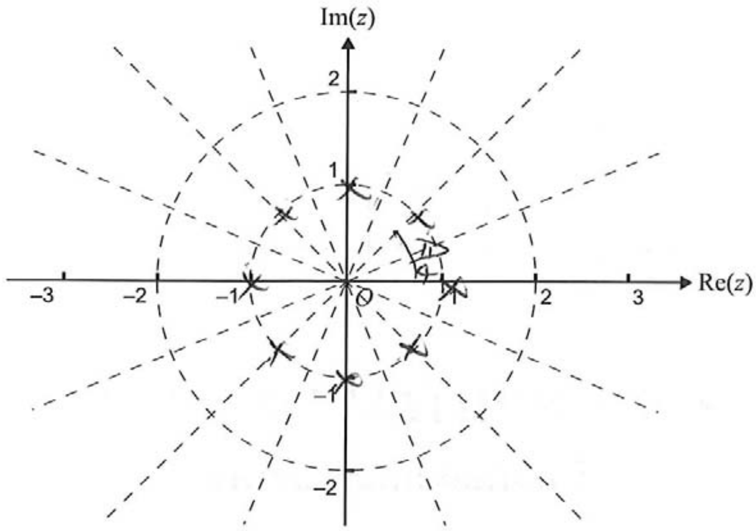
e. if $\left(\frac{\sqrt{2+\sqrt{2}}}{2}+\frac{\sqrt{2-\sqrt{2}}}{2}i\right)^n$ is a real number

$$=\left[\text{cis}\left(\frac{\pi}{8}\right)\right]^n=\text{cis}\left(\frac{n\pi}{8}\right)=\pm1+0i=\cos\left(\frac{n\pi}{8}\right)+i\sin\left(\frac{n\pi}{8}\right)$$

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

$n=8k$ where $k\in J$ or $n=0,\pm8,\pm16,...$

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



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