**Anglo-Chinese Junior College**

*H2 Mathematics 9740*

**2008 JC 2 PRELIM PAPER 1 Solutions**

| | | |
|---|---|---|
| **1** | $\frac{2-x}{\sqrt{1+3x}}=(2-x)(3x)^{-\frac{1}{2}}\left(1+\frac{1}{3x}\right)^{-\frac{1}{2}}$<br>$=\frac{1}{\sqrt{3}}\left(2x^{-\frac{1}{2}}-x^{\frac{1}{2}}\right)\left(1+\frac{1}{3x}\right)^{-\frac{1}{2}}$<br>$=\frac{1}{\sqrt{3}}\left(2x^{-\frac{1}{2}}-x^{\frac{1}{2}}\right)\left(1-\frac{1}{6x}+\frac{1}{24x^2}-......\right)$<br>$=\frac{1}{\sqrt{3}}\left(-x^{\frac{1}{2}}+\frac{13}{6}x^{-\frac{1}{2}}-\frac{3}{8}x^{-\frac{3}{2}}\right)$<br><br>range of validity: $x>\frac{1}{3}$ or $x<-\frac{1}{3}$<br><br>but since $x<-\frac{1}{3}$ will result in the sq rt of a negative number, reject $x<-\frac{1}{3}$.<br>$\therefore$ range of validity: $x>\frac{1}{3}$. | |
| **2** | no. of terms in the sum: $n+2$<br>sum = $\frac{n+2}{2}\left[\left(-\frac{1}{2}+(m-1)d\right)+\left(-\frac{1}{2}+(m+n)d\right)\right]$<br>= $\frac{n+2}{2}\left[-1+(2m+n-1)d\right]$ | |
| **3** | **<u>Method 1</u>**<br>$\int e^x\left(\cos^2 x-1\right)\ dx=\int e^x\left(\frac{\cos 2x+1}{2}-1\right)\ dx$<br>$=\frac{1}{2}\int e^x\cos 2x-e^x\ dx$<br><br>$I=\int e^x\cos 2x\ \ dx$     $u_1=e^x,\ \frac{dv_1}{dx}=\cos 2x$<br>$=\frac{1}{2}e^x\sin 2x-\frac{1}{2}\int e^x\sin 2x\ \ dx$     $\frac{du_1}{dx}=e^x,\ v_1=\frac{1}{2}\sin 2x$<br>$=\frac{1}{2}e^x\sin 2x-\frac{1}{2}\left(-\frac{1}{2}e^x\cos 2x+\frac{1}{2}\int e^x\cos 2x\ \ dx\right)$     $u_2=e^x,\ \frac{dv_2}{dx}=\sin 2x$<br>$=\frac{1}{2}e^x\sin 2x+\frac{1}{4}e^x\cos 2x-\frac{1}{4}I$     $\frac{du_2}{dx}=e^x,\ v_2=-\frac{1}{2}\cos 2x$<br>$\frac{5}{4}I=\frac{1}{2}e^x\sin 2x+\frac{1}{4}e^x\cos 2x$<br>$I=\frac{2}{5}e^x\sin 2x+\frac{1}{5}e^x\cos 2x$<br><br>Thus,<br>$\int e^x\left(\cos^2 x-1\right)\ dx=\frac{1}{2}\left[\frac{2}{5}e^x\sin 2x+\frac{1}{5}e^x\cos 2x\right]-\frac{1}{2}e^x+C$<br>$=\frac{1}{5}e^x\sin 2x+\frac{1}{10}e^x\cos 2x-\frac{1}{2}e^x+C$ | |

**Method 2**

$$\int e^x\left(\cos^2 x-1\right)\ dx=\int e^x\cos^2 x\,dx-\int e^x\ \ dx$$

$$\int e^x\cos^2 x\,dx \qquad \frac{dv_1}{dx}=e^x,\ u_1=\cos^2 x$$

$$v_1=e^x,\ \frac{du_1}{dx}=-\sin 2x$$

$$=-e^x\cos^2 x+\int e^x\sin 2x\ \ dx \qquad u_2=e^x,\ \frac{dv_2}{dx}=\sin 2x$$

$$\frac{du_2}{dx}=e^x,\ v_2=-\frac{1}{2}\cos 2x$$

$$=-e^x\cos^2 x-\frac{1}{2}e^x\cos 2x+\frac{1}{2}\int e^x\cos 2x\ \ dx \qquad u_3=e^x,\ \frac{dv_3}{dx}=\cos 2x$$

$$\frac{du_3}{dx}=e^x,\ v_3=\frac{1}{2}\sin 2x$$

$$=-e^x\cos^2 x-\frac{1}{2}e^x\cos 2x+\frac{1}{2}\left(\frac{1}{2}e^x\sin 2x-\frac{1}{2}\int e^x\sin 2x\ \ dx\right)$$

$$=-e^x\cos^2 x-\frac{1}{2}e^x\cos 2x+\frac{1}{2}e^x\sin 2x-\frac{1}{4}\int e^x\sin 2x\ \ dx$$

Let $I=\int e^x\sin 2x\ \ dx$

Then,

$$-e^x\cos^2 x+I=-e^x\cos^2 x-\frac{1}{2}e^x\cos 2x+\frac{1}{2}e^x\sin 2x-\frac{1}{4}I$$

$$\frac{5}{4}I=\frac{1}{4}e^x\sin 2x-\frac{1}{2}e^x\cos 2x$$

$$I=\frac{1}{5}e^x\sin 2x-\frac{2}{5}e^x\cos 2x$$

Thus, $\int e^x\left(\cos^2 x-1\right)\ dx=\frac{1}{5}e^x\sin 2x-\frac{2}{5}e^x\cos 2x-e^x+C$

**4**

$x:\ 10,-\frac{5}{2},\frac{5}{8},-\frac{5}{32},\ldots$

$y:\ 5,-\frac{5}{4},\frac{5}{16},-\frac{5}{64},\ldots$

$x$: GP with $a=10$ and $r=-\frac{1}{4}$

$y$: GP with $a=5$ and $r=-\frac{1}{4}$

$x:\ S_\infty=\dfrac{10}{1+\frac{1}{4}}=8,\qquad y:\ S_\infty=\dfrac{5}{1+\frac{1}{4}}=4$

the ant will eventually end up at $(8,4)$.

<table>
<tr>
<td rowspan="3">5</td>
<td>For $\lvert x-2\rvert \ge 0 \Rightarrow x \ge 2$,<br>$x(x-2) \ge 1$<br>$x^2 - 2x - 1 \ge 0$<br>$(x-1)^2 - 2 \ge 0$<br>$(x-1-\sqrt{2})(x-1+\sqrt{2}) \ge 0$<br>$x \le 1-\sqrt{2}$ (N.A.) or $x \ge 1+\sqrt{2}$</td>
<td>ALTERNATIVE:<br>For $\lvert x-2\rvert < 0 \Rightarrow x < 2$,<br>$x(2-x) \ge 1$<br>$x^2 - 2x + 1 \le 0$<br>$(x-1)^2 \le 0$<br>No real solution except $x = 1$</td>
<td rowspan="3"></td>
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<tr>
<td colspan="2">Hence, $x \ge 1+\sqrt{2},\ x = 1$</td>
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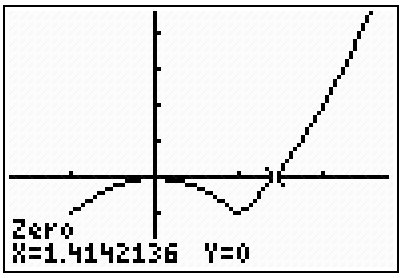
<td>$(x+1)\lvert x-1\rvert \ge 1$<br>Let $u = x + 1$, $u\lvert u-2\rvert \le 1$ B1<br>$\therefore u = x+1 \ge 1+\sqrt{2} \Rightarrow x \ge \sqrt{2}$,<br>$u = x+1 = 1 \Rightarrow x = 0$<br>B2</td>
<td>OTHERWISE<br><br>sketch of $y = (x+1)\lvert x-1\rvert - 1$<br>hence, $x \ge \sqrt{2},\ x = 0$</td>
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<tr>
<td>6</td>
<td colspan="2">$x = \ln(\cos\theta)$, $\qquad y = \ln(\sin\theta)$<br>$\frac{dx}{d\theta} = -\frac{\sin\theta}{\cos\theta}$ $\qquad \frac{dy}{d\theta} = \frac{\cos\theta}{\sin\theta}$<br>$$\frac{dy}{dx} = \frac{\cos\theta}{\sin\theta}\left(-\frac{\cos\theta}{\sin\theta}\right)$$<br>$$= -\frac{\cos^2\theta}{\sin^2\theta}$$<br>when $\theta = \frac{\pi}{4}$, $\quad \frac{dy}{dx} = -1$<br>$$\Rightarrow \frac{y - \ln\frac{1}{\sqrt{2}}}{x - \ln\frac{1}{\sqrt{2}}} = -1$$<br>The equation of tangent is $y = -x - \ln 2$.<br><br>If this tangent meets the curve again,<br>$\ln(\sin\theta) = -\ln(\cos\theta) - \ln 2$<br>$\ln(\sin 2\theta) = 0$<br>$\sin 2\theta = 1$<br>$\therefore 2\theta = \frac{\pi}{2} \quad \Rightarrow \theta = \frac{\pi}{4} \qquad \left(0 < \theta < \frac{\pi}{2}\right)$<br>The tangent will not meet the curve again as there is only one solution in range $0 < \theta < \frac{\pi}{2}$ i.e. $\theta = \frac{\pi}{4}$.</td>
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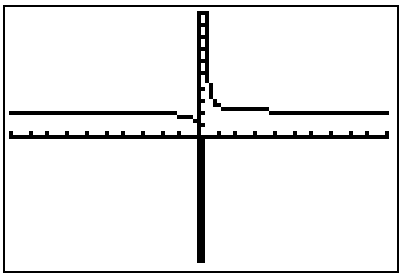
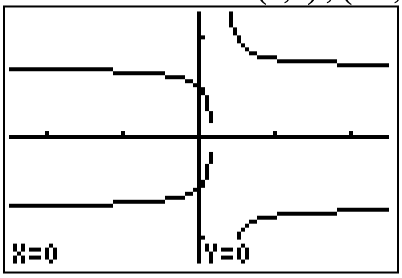
| **7** | By Newton's Law of Cooling,<br>$\frac{d\theta}{dt}=k(\theta-20)$<br>$\int\frac{d\theta}{\theta-20}=\int k\,dt$<br>$\therefore\ \ln\lvert\theta-20\rvert=kt+C$ — ①<br><br>**<u>Method 1</u>**<br>Given: when $t=t_1$, $\theta=60$ — **A**<br>When $t=t_1+10$, $\theta=45$ — **B**<br>From ①: $\ln 40=kt_1+C$, $\ln 25=kt_1+10k+C$<br>$\Rightarrow\ \ln\frac{25}{40}=10k$<br>$\Rightarrow\ k=\frac{1}{10}\ln\frac{5}{8}$ — ②<br>Also given: $t=t_2$, $\theta=?$<br>$t=t_2+20$, $\theta=45$ — **C**<br>From ① & ②: $\ln\lvert\theta-20\rvert=\left(\frac{1}{10}\ln\frac{5}{8}\right)t_2+C_1$,<br>$\ln 25=\left(\frac{1}{10}\ln\frac{5}{8}\right)t_2+20\left(\frac{1}{10}\ln\frac{5}{8}\right)+C_1$<br>$\Rightarrow\ \ln\frac{25}{\theta-20}=2\ln\frac{5}{8}$ [Modulus can be removed as initial temperature is higher than 45°C, hence $\theta-20>0$.]<br>$\Rightarrow\ \theta=\frac{25}{\left(5/8\right)^2}+20=84\ °\text{C}$<br><br>**<u>Method 2</u>**<br>Given: $t=0$, $\theta=60$ — **A**<br>$t=10$, $\theta=45$ — **B**<br>From ①: $\ln 40=C$, $\ln 25=10k+C$<br>$\Rightarrow\ \ln\frac{25}{40}=10k$<br>$\Rightarrow\ k=\frac{1}{10}\ln\frac{5}{8}$ — ②<br><br>Also given: $t=0$, $\theta=?$<br>$t=20$, $\theta=45$ — **C**<br>From ① & ②: $\ln\lvert\theta-20\rvert=\left(\frac{1}{10}\ln\frac{5}{8}\right)t_2+C_1$,<br>$\ln 25=20\left(\frac{1}{10}\ln\frac{5}{8}\right)+C_1$<br>$\Rightarrow\ \ln\frac{25}{\theta-20}=2\ln\frac{5}{8}$ [Modulus can be removed as initial temperature is higher than 45°C, hence $\theta-20>0$.]<br>$\Rightarrow\ \frac{25}{\theta-20}=\left(\frac{5}{8}\right)^2$<br>$\Rightarrow\ \theta=\frac{25}{\left(5/8\right)^2}+20=84\ °\text{C}$ | |

**8** $a=6, \quad b=-1$



Asymptotes $y=2, \quad x=\frac{1}{3}$

Axial intersection : (0,1) , (1/6,0)




Asymptotes $y=\pm\sqrt{2}, \quad x=\frac{1}{3}$

Axial intersection : (0,1) , (0,-1)

$$y=\frac{6x-1}{3x-1}=2+\frac{1}{3x-1}$$

I : A translation of 1 unit in direction of the positive $x$ – axis
II : A scaling parallel to the $x$ – axis with scale factor $\frac{1}{3}$ units
III: A translation of 2 unit in direction of the positive y – axis

**OR**
I : A translation of 2 unit in direction of the positive y – axis
II : A translation of 1 unit in direction of the positive $x$ – axis
III : A scaling parallel to the $x$ – axis with scale factor $\frac{1}{3}$ units

**OR**
I : A translation of 1 unit in direction of the positive $x$ – axis
II : A translation of 2 unit in direction of the positive y – axis
III: A scaling parallel to the $x$ – axis with scale factor $\frac{1}{3}$ units

**OR**
I : A scaling parallel to the $x$ – axis with scale factor $\frac{1}{3}$ units
II : A translation of $\frac{1}{3}$ unit in direction of the positive $x$ – axis
III: A translation of 2 unit in direction of the positive y – axis

**OR**
I : A scaling parallel to the $x$ – axis with scale factor $\frac{1}{3}$ units
II : A translation of 2 unit in direction of the positive y – axis
III: A translation of $\frac{1}{3}$ unit in direction of the positive $x$ – axis

**OR**
I : A translation of 2 unit in direction of the positive y – axis
II: A scaling parallel to the $x$ – axis with scale factor $\frac{1}{3}$ units
III :A translation of $\frac{1}{3}$ unit in direction of the positive $x$ – axis

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| **9** | $y=\sin^{-1}x \;\Rightarrow\; \dfrac{dy}{dx}=\dfrac{1}{\sqrt{1-x^2}}$ .<br>$\Rightarrow\; \sqrt{1-x^2}\,\dfrac{dy}{dx}=1$<br>diff. w.r.t $x$,<br>$\sqrt{1-x^2}\,\dfrac{d^2y}{dx^2}+\dfrac{dy}{dx}\left(\dfrac{-2x}{2\sqrt{1-x^2}}\right)=0$<br>$\left(1-x^2\right)\dfrac{d^2y}{dx^2}-x\dfrac{dy}{dx}=0$<br>diff. w.r.t $x$,<br>$\left(1-x^2\right)\dfrac{d^3y}{dx^3}+\dfrac{d^2y}{dx^2}(-2x)-\left(x\dfrac{d^2y}{dx^2}+\dfrac{dy}{dx}\right)=0$<br>$\left(1-x^2\right)\dfrac{d^3y}{dx^3}-3x\dfrac{d^2y}{dx^2}-\dfrac{dy}{dx}=0$ (*QED*)<br>diff. w.r.t $x$,<br>$\left(1-x^2\right)\dfrac{d^4y}{dx^4}-5x\dfrac{d^3y}{dx^3}-4\dfrac{d^2y}{dx^2}=0$<br>diff. w.r.t $x$,<br>$\left(1-x^2\right)\dfrac{d^5y}{dx^5}-7x\dfrac{d^4y}{dx^4}-9\dfrac{d^3y}{dx^3}=0$<br>$f(0)=0,\quad f'(0)=1,\quad f''(0)=0,\quad f'''(0)=1,\quad f''''(0)=0,\quad f'''''(0)=9$<br>$y=x+\dfrac{x^3}{6}+\dfrac{3x^5}{40}+\ldots$<br>$\dfrac{1}{\sqrt{1-x^2}}=\dfrac{d}{dx}\sin^{-1}x$<br>$=\dfrac{d}{dx}\left(x+\dfrac{x^3}{6}+\dfrac{3x^5}{40}+\ldots\right)$<br>$=1+\dfrac{x^2}{2}+\dfrac{3x^4}{8}+\ldots$<br>Using $x=\dfrac{1}{2}$, $\dfrac{1}{\sqrt{1-\left(\frac{1}{2}\right)^2}}=1+\dfrac{\left(\frac{1}{2}\right)^2}{2}+\dfrac{3\left(\frac{1}{2}\right)^4}{8}+\ldots$<br>$\dfrac{1}{\sqrt{1-\left(\frac{1}{2}\right)^2}}=1+\dfrac{\left(\frac{1}{2}\right)^2}{2}+\dfrac{3\left(\frac{1}{2}\right)^4}{8}+\ldots$<br>$\Rightarrow\; \sqrt{3}=\dfrac{256}{147}$ | |
| | | |

**10 (a)**

Area $= \int_0^{1/4} x^2\sqrt{1-4x^2}\ dx$

Let $x = \frac{1}{2}\sin\theta \Rightarrow \frac{dx}{d\theta} = \frac{1}{2}\cos\theta$

When $x = 0,\ \theta = 0$; $x = \frac{1}{4},\ \theta = \frac{\pi}{6}$.

Substituting,

$$\text{Area} = \int_0^{\pi/6} \frac{1}{4}\sin^2\theta\sqrt{1-\sin^2\theta}\cdot\frac{1}{2}\cos\theta\, d\theta$$

$$= \frac{1}{8}\int_0^{\pi/6}\sin^2\theta\cos^2\theta\, d\theta$$

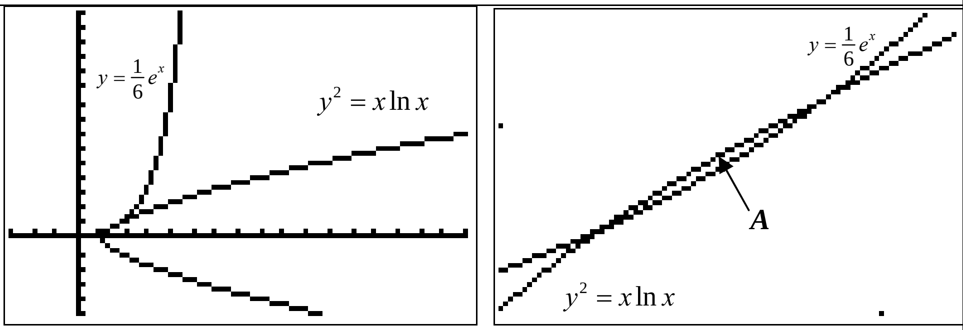
$$= \frac{1}{32}\int_0^{\pi/6}\sin^2 2\theta\ d\theta$$

$$= \frac{1}{64}\int_0^{\pi/6} 1-\cos 4\theta\ d\theta$$

$$= \frac{1}{64}\left[\theta - \frac{1}{4}\sin 4\theta\right]_0^{\pi/6}$$

$$= \frac{1}{64}\left[\frac{\pi}{6} - \frac{\sqrt{3}}{8}\right]$$

**10 (b)**




From G.C., approximate coordinates of the points of intersection of the two curves are $(1.36759, 0.65435)$ and $(1.87156, 1.08307)$.

$$\text{Volume} = \pi\int_{1.36759}^{1.87156} x\ln x - \left(\frac{1}{6}e^x\right)^2\ dx = 0.0766 \text{ (3 s.f.)}$$

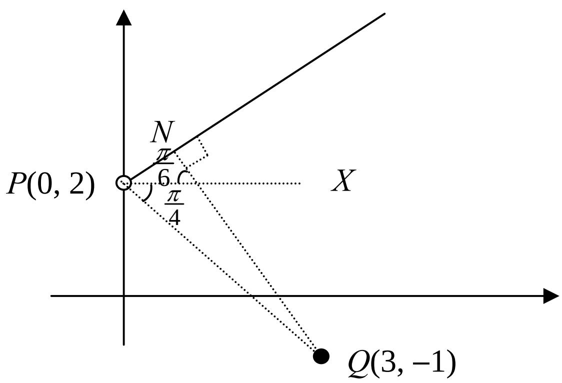
**11**

$\arg(iz+2) = \frac{2}{3}\pi$

$\arg[i(z-2i)] = \frac{2}{3}\pi$

$\arg i + \arg(z-2i) = \frac{2}{3}\pi$

$\arg(z-2i) = \frac{2}{3}\pi - \frac{\pi}{6} = \frac{\pi}{6}$




$N\hat{P}Q = \frac{\pi}{4} + \frac{\pi}{6} = \frac{5\pi}{12}$

$PQ = \sqrt{3^2+3^2} = 3\sqrt{2}$

$\sin\frac{5\pi}{12} = \frac{NQ}{3\sqrt{2}} \Rightarrow NQ = 4.10$ (3 sig fig)

$\therefore m = 4.10,\ m \geq 3\sqrt{2}$

**12 (i)** Asymptotes $y = x + a, \quad x = 2$

**(ii)**

$$\frac{dy}{dx} = 1 - \frac{4a^2}{(x-2)^2}$$

For stationary points, $\frac{dy}{dx} = 0$

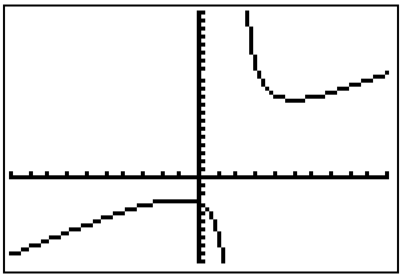
$$0 = 1 - \frac{4a^2}{(x-2)^2}$$

$$x = 2 \pm 2a$$

when $x = 2 + 2a, y = 2 + 5a$

when $x = 2 - 2a, y = 2 - 3a$

**(iii)**



**13**

$$w^3 = 1 \Rightarrow w = e^{\frac{2k\pi}{3}i}, \; k = -1, \; 0, \; 1$$

$$(z+i)^3 + (z-i)^3 = 0$$
$$(z+i)^3 = -(z-i)^3 = (-1)^3(z-i)^3$$
$$\left(\frac{z+i}{-z+i}\right)^3 = 1$$
$$\frac{z+i}{-z+i} = e^{\frac{2k\pi}{3}i}$$

$$z = \frac{i(-1+e^{\frac{2k\pi}{3}i})}{1+e^{\frac{2k\pi}{3}i}}$$
$$= \frac{i(-1+\cos\frac{2k\pi}{3} + i\sin\frac{2k\pi}{3})}{1+\cos\frac{2k\pi}{3} + i\sin\frac{2k\pi}{3}}$$
$$= \frac{i\left[-1+\left(1-2\sin^2\frac{k\pi}{3}\right)+i\left(2\sin\frac{k\pi}{3}\cos\frac{k\pi}{3}\right)\right]}{1+\left(2\cos\frac{k\pi}{3}-1\right)+i\left(2\sin\frac{k\pi}{3}\cos\frac{k\pi}{3}\right)}$$
$$= \frac{-2\sin\frac{k\pi}{3}\left(\cos\frac{k\pi}{3}+i\sin\frac{k\pi}{3}\right)}{2\cos\frac{k\pi}{3}\left(\cos\frac{k\pi}{3}+i\sin\frac{k\pi}{3}\right)}$$
$$= -\tan\frac{k\pi}{3}$$

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| | ALTERNATIVE:<br>$z=\frac{i(-1+e^{\frac{2k\pi}{3}i})}{1+e^{\frac{2k\pi}{3}i}}$<br>$=\frac{i(-1+e^{\frac{2k\pi}{3}i})}{1+e^{\frac{2k\pi}{3}i}}\cdot\frac{e^{-\frac{k\pi}{3}i}}{e^{-\frac{k\pi}{3}i}}$<br>$=\frac{i(-e^{-\frac{k\pi}{3}i}+e^{\frac{k\pi}{3}i})}{e^{-\frac{k\pi}{3}i}+e^{\frac{k\pi}{3}i}}$<br>$=\frac{i(2i\sin\frac{k\pi}{3})}{2\cos\frac{k\pi}{3}}$<br>$=-\tan\frac{k\pi}{3}$<br><br>$(z+i)^3+(z-i)^3=0$<br>$\left(z^3+3z^2i-3z-i\right)+\left(z^3-3z^2i-3zi^2+i\right)=0$<br>$2\left(z^3-3z\right)=0$<br>$z\left(z^2-3\right)=0$<br>$z=0,\ \pm\sqrt{3}$<br>Since $z=-\tan\frac{\pi}{3}$ is negative $\therefore \tan\frac{\pi}{3}=\sqrt{3}$. | |

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| **14(i)** | $\measuredangle BOC=\cos^{-1}\left[\frac{\begin{pmatrix}1\\3\\1\end{pmatrix}\cdot\begin{pmatrix}1\\-2\\2\end{pmatrix}}{\sqrt{11}\sqrt{9}}\right]=107.5^\circ$. (1 d.p) | |
| **(ii)** | Area of $\Delta OBC=\frac{1}{2}\left\|\overrightarrow{OB}\right\|\left\|\overrightarrow{OC}\right\|\sin\left(107.5^\circ\right)$<br>$=\frac{1}{2}\sqrt{11}\sqrt{81}\sin\left(107.5^\circ\right)$<br>$=14.2\text{ units}^2$ | |
| **(iii)** | $\overrightarrow{CP}=\begin{pmatrix}2-2t\\1+4t\\3-4t\end{pmatrix}-\begin{pmatrix}3\\-6\\6\end{pmatrix}=\begin{pmatrix}-1-2t\\7+4t\\-3-4t\end{pmatrix}$ , $\overrightarrow{CB}=\begin{pmatrix}-2\\9\\-5\end{pmatrix}$<br>Since,<br>$\left\|\overrightarrow{CP}\cdot\frac{\overrightarrow{CB}}{\left\|\overrightarrow{CB}\right\|}\right\|=\sqrt{110}$<br>$\left\|\frac{\begin{pmatrix}-1-2t\\7+4t\\-3-4t\end{pmatrix}\cdot\begin{pmatrix}-2\\9\\-5\end{pmatrix}}{\sqrt{110}}\right\|=\sqrt{110}$ | |

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| | $60t + 80 = 110$ or $60t + 80 = -110$<br>$t = \frac{1}{2}$ or $-3\frac{1}{6}$ $(-3.17)$ | |
| **(iv)** | $\overrightarrow{PA} = -2t\begin{pmatrix}-1\\2\\-2\end{pmatrix}$ $\overrightarrow{AB} = \begin{pmatrix}-1\\2\\-2\end{pmatrix}$<br>Since $\overrightarrow{PA} = -2t\left(\overrightarrow{AB}\right)$, hence, *P*, *A* and *B* are collinear for all values of *t*.<br>[OR $\overrightarrow{PB} = (1-2t)\left(\overrightarrow{AB}\right)$, OR $\overrightarrow{PB} = \left(\frac{-1}{2t}+1\right)\left(\overrightarrow{PA}\right)$] | |
| **(v)** | $\Delta OBC$ and $\Delta OPC$ share the same base of *OC*. Since $\overrightarrow{OC} // \overrightarrow{BP}$, $\Delta OBC$ and $\Delta OPC$ also has the same perpendicular height.<br>$\therefore$ Area of $\Delta OPC$ = Area of $\Delta OBC = 14.2$ units$^2$. | |