**MEI STRUCTURED MATHEMATICS**          **2603(A)**

Pure Mathematics 3

**Section A**

Thursday          **9 JANUARY 2003**          Afternoon          1 hour 20 minutes

Additional materials:
   Answer booklet
   Graph paper
   MEI Examination Formulae and Tables (MF12)

**TIME**     1 hour 20 minutes

## INSTRUCTIONS TO CANDIDATES

*   Write your Name, Centre Number and Candidate Number in the spaces provided on the answer booklet.
*   Answer **all** questions.
*   You are permitted to use a graphical calculator in this paper.

## INFORMATION FOR CANDIDATES

*   The allocation of marks is given in brackets [ ] at the end of each question or part question.
*   You are advised that an answer may receive no marks unless you show sufficient detail of the working to indicate that a correct method is being used.
*   Final answers should be given to a degree of accuracy appropriate to the context.
*   The total number of marks for this paper is 60.

## NOTE

*   This paper will be followed by **Section B: Comprehension**.

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**This question paper consists of 4 printed pages.**

1   (a)  Find the coefficient of $x^3$ in the binomial expansion of $\sqrt{1+2x}$.                    [3]

    (b)  Solve the equation $\sin 2x = \cos x$ for $0 \leqslant x \leqslant 2\pi$, giving your answers in terms of $\pi$.       [5]

    (c)  By using the substitution $u = \sin x$, or otherwise, find $\displaystyle\int \sin^2 x \cos x\, dx$.

         Hence evaluate $\displaystyle\int_0^{\frac{1}{2}\pi} \sin^2 x \cos x\, dx$.                    [4]

    (d)  You are given that $y = 2^x$. By finding $\ln y$ in terms of $x$, and differentiating implicitly, or

         otherwise, find $\dfrac{dy}{dx}$ in terms of $x$.                    [4]

                                                                          [Total 16]


2   Fig. 2 shows the graph of the curve with parametric equations
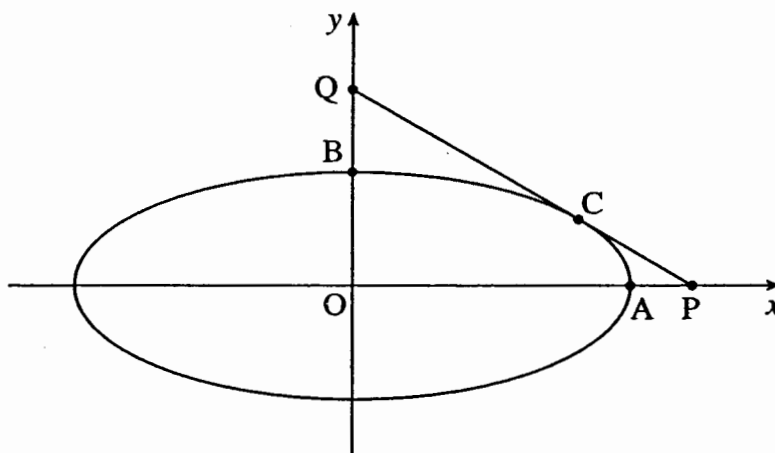
         $$x = 4 \cos \theta, \quad y = 3 \sin \theta, \qquad 0 \leqslant \theta < 2\pi.$$



**Fig. 2**

    (i)   Find the coordinates of the points A and B.                    [2]

    (ii)  The point C has parameter $\theta = \frac{1}{4}\pi$. Find the exact coordinates of C.      [2]

    (iii) Find $\dfrac{dy}{dx}$ in terms of $\theta$.

          Hence show that the equation of the tangent to the curve at C is $3x + 4y = 12\sqrt{2}$.    [5]

    (iv)  This tangent meets the $x$- and $y$-axes at P and Q respectively. Find the area of the triangle POQ.
                                                                          [2]

    (v)   Find the cartesian equation of the curve.                    [3]

                                                                          [Total 14]
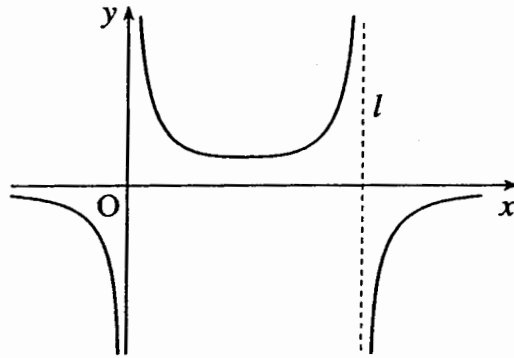
3    Fig. 3 shows the graph of $y = \dfrac{1}{x(2-x)}$.



**Fig. 3**

(i) Write down the equation of the asymptote $l$.    [1]

(ii) Express $\dfrac{1}{x(2-x)}$ in partial fractions.

Hence find the exact area enclosed by the graph of $y = \dfrac{1}{x(2-x)}$, the $x$-axis and the lines $x = 1$ and $x = 1.5$. Express your answer in the form $a \ln b$.    [8]

You are given that $z$ satisfies the differential equation

$$\frac{1}{z}\frac{dz}{dx} = \frac{1}{x(2-x)}$$

and that $z = 1$ when $x = 1$.

(iii) Use integration to solve this equation, and hence show that

$$z^2 = \frac{x}{2-x}.$$    [6]

[Total 15]

**[Turn over**

**4** The lines $l_1$ and $l_2$ have the following vector equations.

$$l_1: \quad \mathbf{r} = \begin{pmatrix} 1 \\ 8 \\ 8 \end{pmatrix} + \lambda \begin{pmatrix} 0 \\ 3 \\ 4 \end{pmatrix}$$

$$l_2: \quad \mathbf{r} = \begin{pmatrix} 3 \\ 3 \\ -1 \end{pmatrix} + \mu \begin{pmatrix} 2 \\ 1 \\ -1 \end{pmatrix}$$

(i) Verify that the point P $(1, 2, 0)$ lies on both the lines $l_1$ and $l_2$. [3]

(ii) Find the acute angle between the two lines. [5]

A plane has cartesian equation $2x - y + z = 12$.

(iii) Write down a vector normal to the plane. Hence write down a vector equation for the line through P perpendicular to the plane. [2]

(iv) Find where this line meets the plane, and hence find the distance of P from the plane. [5]

[Total 15]

# Mark Scheme

| | | |
|---|---|---|
| **1 (a)** $$\frac{\frac{1}{2}(-\frac{1}{2})(-\frac{3}{2})}{3!}(2x)^3$$ $$= \frac{1}{2}x^3 \text{, so } \frac{1}{2}$$ | M1 A1 A1 cao [3] | Binomial series with index ½. Correct expression for term in $x^3$. Simplified. Accept ½ $x^3$. |
| **(b)**      $\sin 2x = \cos x$ $\Rightarrow 2\sin x \cos x = \cos x$ $\Rightarrow 2\sin x \cos x - \cos x = 0$ $\Rightarrow \cos x (2\sin x - 1) = 0$ $\Rightarrow \cos x = 0, x = \pi/2, 3\pi/2$ or $\sin x = 1/2, x = \pi/6, 5\pi/6$ | M1 B1 ,B1 B1 , B1 [5] | $\sin 2x = 2\sin x \cos x$ used in the equation. Answers w.w. B1,2,3 or 5. Answers as decimals or in degrees- follow M.S. and −1 |
| **(c)** let $u = \sin x$, $du = \cos x \, dx$ $\Rightarrow \int \sin^2 x \cos x \, dx = \int u^2 \, du$ $\qquad = u^3/3 = \frac{1}{3}\sin^3 x + c$ $\int_0^{\pi/2} \sin^2 x \cos x \, dx = \left[\frac{1}{3}\sin^3 x\right]_0^{\pi/2}$ $\qquad = \frac{1}{3}\sin^3 \frac{\pi}{2} - \frac{1}{3}\sin^3 0$ $\qquad = \frac{1}{3}$ | M1 A1 M1 A1 cao [4] | $\int u^2 \, du$. For I by P, or by inspection, giveB2 for correct result or 0. $\frac{1}{3}\sin^3 x + c$ Condone no $c$. .Accept $\frac{1}{3}u^3 + c$. substituting correct limits c.a.o. refers to whole of (c). |
| **(d)**      $y = 2^x$ $\Rightarrow \ln y = x \ln 2$ $\Rightarrow \frac{1}{y}\frac{dy}{dx} = \ln 2$ **OR** $y = e^{x\ln2}$ $\Rightarrow \frac{dy}{dx} = y \ln 2$ **OR** $\frac{dy}{dx} = \ln2 \, e^{x\ln2}$ $\qquad = 2^x \ln 2$ | B1 B1, B1 B1 cao [4] Total [16] | $x \ln 2$ $\frac{1}{y}\frac{dy}{dx}, \ln 2$ **OR** B1 $e^{x\ln2}$ **OR** B2 cao $\ln2 e^{x\ln2}$ |

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|---|---|---|---|
| **2 (i)**    A is $(4, 0)$ , B is $(0, 3)$ | B1, B1 [2] | | |
| **(ii)** $\theta = \pi/4 \Rightarrow x = 4 \times \sqrt{2}/2 = 2\sqrt{2}$ <br> $\qquad\qquad\qquad y = 3\sqrt{2}/2$ | B1 <br> B1 <br> [2] | Allow $4/\sqrt{2}$, $3/\sqrt{2}$ <br> SCB1 both correct but approximate. 2.83, 2.12. | |
| **(iii)**    $\dfrac{dy}{dx} = \dfrac{dy/d\theta}{dx/d\theta}$ <br><br> $\qquad = -\dfrac{3\cos\theta}{4\sin\theta}$ <br> When $\theta = \pi/4$ $dy/dx = -3/4$. <br> Equation of tangent is <br><br> $y - \dfrac{3\sqrt{2}}{2} = -\dfrac{3}{4}(x - 2\sqrt{2})$ <br> $\Rightarrow \;\; 4y - 6\sqrt{2} = -3x + 6\sqrt{2}$ <br> $\Rightarrow \;\; 3x + 4y = 12\sqrt{2}$   * <br><br><br> Accept verification of the given equation, i.e. the equation is satisfied by $(2\sqrt{2}, 3\sqrt{2}/2)$ <u>and</u> the gradient is $-3/4$, from <u>both</u> the equation and $dy/dx$. | M1 <br><br> A1 <br> A1ft <br><br><br> M1 <br><br><br> E1 <br> [5] <br><br><br> M1 <br> A1 <br> E1 | $\dfrac{dy}{dx} = \dfrac{dy/d\theta}{dx/d\theta}$ <br><br> Seen or implied in subsequent work <br><br> ft their $x$ and $y$ from (ii) and their gradient. No $\theta$ seen. <br><br><br><br> Both attempted <br> $dy/dx = -3/4$ <br> All detail correct | |
| **(iv)**   When $y = 0$, $x = 4\sqrt{2}$ <br>      when $x = 0$, $y = 3\sqrt{2}$ <br><br> $\Rightarrow$ area of POQ $= 1/2 \times 4\sqrt{2} \times 3\sqrt{2}$ <br> $\qquad\qquad\qquad = 12$ square units | B1 <br><br><br> B1ft <br> [2] | Accept decimal equivalents 5.66, 4.24 <br><br> Accept answer rounding to 12 | |
| **v)** $\cos\theta = x/4$ , $\sin\theta = y/3$    s.o.i. <br> $\Rightarrow \cos^2\theta + \sin^2\theta = (x/4)^2 + (y/3)^2 = 1$ <br><br> $\Rightarrow \dfrac{x^2}{16} + \dfrac{y^2}{9} = 1$ Accept $\dfrac{x^2}{4^2} + \dfrac{y^2}{3^2} = 1$ | M1 <br> M1 <br><br> A1 <br> [3] <br> Total [14] | Allow the first M1 for $\cos\theta = x/4$ and $y = 3\sin(\cos^{-1}x/4)$. $y = 3/4\ \sqrt{(16 - x^2)}$ may then gain M1 A1 | |

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| 3 (i) $x = 2$   Allow $l = 2$ | B1 [1] | |

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| (ii)   $\dfrac{1}{x(2-x)} = \dfrac{A}{x} + \dfrac{B}{2-x}$ <br><br> $\Rightarrow$   $1 = A(2-x) + Bx$ <br> $x = 0 \Rightarrow 1 = 2A \Rightarrow A = 1/2$ <br> $x = 2 \Rightarrow 1 = 2B \Rightarrow B = 1/2$ <br><br> $\Rightarrow \dfrac{1}{x(2-x)} = \dfrac{1}{2x} + \dfrac{1}{2(2-x)}$ <br><br> $A = \displaystyle\int_{1}^{1.5} \left( \dfrac{1}{x(2-x)} \right) dx$ <br><br> $= \dfrac{1}{2} \displaystyle\int_{1}^{1.5} \dfrac{1}{x} + \dfrac{1}{2-x} \, dx$ <br><br> $= \dfrac{1}{2} \left[ \ln x - \ln(2-x) \right]_{1}^{1.5}$ <br><br> $= \dfrac{1}{2}(\ln 1.5 - \ln 0.5)$ <br><br> $= \dfrac{1}{2} \ln \dfrac{1.5}{0.5} = \dfrac{1}{2} \ln 3$ or $\ln \sqrt{3}$ | M1 <br> A1 <br> A1 <br><br><br><br><br> M1 <br><br><br><br><br><br> A1ft <br><br><br><br> M1 <br> A1ft <br><br> A1 cao[8] | s.o.i. <br><br><br><br><br><br><br><br> Integral and limits <br><br><br><br><br><br> $\dfrac{1}{2}[\ln x - \ln(2-x)]$ or <br> equivalent. ft their PFs <br><br> substituting their limits <br> ft their integration. |

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| (iii)   $\dfrac{1}{z} \dfrac{dz}{dx} = \dfrac{1}{x(2-x)}$ <br><br> $\Rightarrow \displaystyle\int \dfrac{1}{z} \, dz = \displaystyle\int \dfrac{1}{x(2-x)} \, dx$ <br><br> $\Rightarrow \ln z = \dfrac{1}{2}[\ln x - \ln(2-x)] + c$ <br><br> When $x = 1, z = 1 \Rightarrow 0 = 0 - 0 + c$ <br><br> $\Rightarrow \ln z = \dfrac{1}{2}[\ln x - \ln(2-x)] = \dfrac{1}{2} \ln \dfrac{x}{2-x}$ <br><br> $\Rightarrow 2\ln z = \ln \dfrac{x}{2-x}$ <br><br> $\Rightarrow \ln z^2 = \ln \dfrac{x}{2-x}$ <br><br> $\Rightarrow z^2 = \dfrac{x}{2-x}$ * | M1 <br><br> A1ft <br><br> B1ft <br><br> M1 <br><br><br> M1 <br><br><br> E1 cso [6] <br> Total [15] | Separating variables <br><br> ft their integration in (ii) <br> Condone the absence of $c$ <br> evaluating $c$ <br><br> combining lns May be given at <br> other stages in (ii) or (iii) <br><br> $2\ln z = \ln z^2$ <br><br> or $\dfrac{1}{2} \ln \dfrac{x}{x-2} = \ln \sqrt{\dfrac{x}{x-2}}$ |

| | | |
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| **4 (i)** $\begin{pmatrix} 1 \\ 8+3\lambda \\ 8+4\lambda \end{pmatrix} = \begin{pmatrix} 1 \\ 2 \\ 0 \end{pmatrix}$ when $\lambda = -2$ | M1 A1 | Equating $\lambda = -2$ |
| $\begin{pmatrix} 3+2\mu \\ 3+\mu \\ -1-\mu \end{pmatrix} = \begin{pmatrix} 1 \\ 2 \\ 0 \end{pmatrix}$ when $\mu = -1$ So both lines contain the point ( 1, 2, 0 ) | A1 [3] | $\mu = -1$ |
| **(ii)** Angle between $\begin{pmatrix} 0 \\ 3 \\ 4 \end{pmatrix}$ and $\begin{pmatrix} 2 \\ 1 \\ -1 \end{pmatrix}$ $\cos\theta = \dfrac{0 \times 2 + 3 \times 1 + 4 \times -1}{\sqrt{25 \times 6}}$ $= -\dfrac{1}{5\sqrt{6}}$ $\Rightarrow \theta = 94.7°$ so $85.3°$ | M1 M1 A1,A1 A1 [5] | Give M0 for other vectors but allow the second M1 and A1,A1 for $\cos\theta =$ $(1.3+8.3+8.-1)/\sqrt{(129.19)}$ $-1$ or $1$, $5\sqrt{6}$ $85.3°$, condone $94.7°$. Accept 1.49 radians, condone 1.65 radians |
| **(iii)** $\mathbf{n} = \begin{pmatrix} 2 \\ -1 \\ 1 \end{pmatrix}$ $\mathbf{r} = \begin{pmatrix} 1 \\ 2 \\ 0 \end{pmatrix} + \lambda \begin{pmatrix} 2 \\ -1 \\ 1 \end{pmatrix}$ **(iv)** Substituting $x = 1 + 2\lambda$, $y = 2-\lambda$, $z = \lambda$; $\Rightarrow 2(1+2\lambda) -(2-\lambda) + \lambda = 12$ $\Rightarrow 2 + 4\lambda -2 + \lambda + \lambda = 12$ $\Rightarrow \lambda = 2$ So line meets plane at ( 5, 0, 2 ) Perp distance $= \sqrt{\{(5-1)^2 + (0-2)^2+(2-0)^2\}}$ $= \sqrt{24}$  or  $2\sqrt{6}$  or  $4.90$ | B1 B1ft [2] M1 A1 ft A1 ft M1 A1c.a.o [5] Total [15] | Condone the omission of $\mathbf{r}$. ft their $\mathbf{n}$ ft their line from (iii) or $l_1$ or $l_2$ $\lambda = 2$ Distance formula. |

# Examiner's Report

## 2603 Pure Mathematics 3

### General Comments

Candidates generally performed well on this paper, a very pleasing number scoring marks in the range 65 to 75 with rather more candidates than usual scoring full marks. Very few candidates scored less than ten marks, indeed the number in the range 0 to 20 was quite small. There were some very well presented scripts, neat and accurate, and generally there was less evidence of careless mistakes and very poor algebra.

All questions contained parts which were accessible to all candidates and these parts were answered well; the binomial theorem, coordinates from parametric equations, partial fractions, the angle between two lines and the equation of a line perpendicular to a plane.

In Section B, too, the first three questions presented candidates with few problems except, perhaps, the difficulty of drawing a smooth curve through the given and the calculated points.

### Comments on Individual Questions

### Question 1

(a) The third term of the binomial series for $(1 + 2x)^{1/2}$ was found correctly by most candidates. Occasional errors were an incorrect index $-1/2$; $2x^3$ or $x^3$ instead of $(2x)^3$; or an incorrect product in the numerator of the coefficient $1/2(-3/2)(-5/2)$ instead of $1/2(-1/2)(-3/2)$.

(b) Almost all candidates were able to use the double angle formula for $\sin 2x$ correctly to obtain $2 \sin x \cos x = \cos x$, but very many cancelled $\cos x$ and solved $\sin x = \frac{1}{2}$, thus obtaining only two of the four possible solutions. A few candidates went from the above equation to $2 \sin x = 0$. Another occasional error was to consider only the range $0 \le \theta \le \pi$.

(c) Many candidates are not confident in the use of integration by substitution and the direct statement let $u = \sin x$, $du = \cos x \Rightarrow \int \sin^2 x \cos x \, dx = \int u^2 du$ was only seen from the most able candidates. However, other candidates arrived at the correct result by less direct means. Most candidates getting this far, then went on to complete the question correctly, often changing the limits of the integral to limits for the variable $u$. Unfortunately a few of these candidates failed to return at all to the variable $x$ and so did not answer the first part of the question. However this omission was condoned.

Some candidates confused integration by substitution and integration by parts, having put $u = \sin x$ they attempted to use integration by parts on the integral $\int u^2 \cos x \, dx$.

(d) This question was completed successfully only by the most able candidates.

Most candidates were able to take the first step to obtain $\ln y = x \ln 2$, but although some were able to differentiate $\ln y$ implicitly many differentiated $x \ln 2$ using the product formula and differentiating $\ln 2$ as $\frac{1}{2}$. A small number of candidates went from the above line to $y = e^{\ln x}$ then differentiated correctly to obtain $dy/dx = \ln 2 \, e^{x \ln 2}$.

(a) $\frac{1}{2}$;    (b) $\pi/6$, $\pi/2$, $5\pi/6$, $3\pi/2$;    (c) $1/3 \sin^3 x + c$, $1/3$;    (d) $2^x \ln x$.

### Question 2 (Parametric equations)

(i) Most candidates obtained the correct coordinates for the points A and B in a variety of ways.

(ii) The coordinates of C were also found correctly by many candidates although some found approximate instead of exact values.

(iii) Almost all candidates were able to differentiate the parametric equations correctly and find an expression for $dy/dx$, although just a few had this expression upside down. However many candidates made very heavy weather of the remainder of this part of the question. Some did not substitute the

value of the parameter, $\theta = \pi/4$, immediately, to obtain $dy/dx = -3/4$, or if they did the result was often left as $\dfrac{-3/\sqrt{2}}{4/\sqrt{2}}$ for substitution into the equation of the tangent.

Just a few candidates attempted to verify that the given equation was the equation of the tangent at C but most of these candidates failed to check <u>both</u> the gradient <u>and</u> the point of contact.

(iv)    Despite some difficulty in manipulating surds in part (iii) almost all candidates were able to obtain the correct coordinates for P and Q, and find the area of the triangle OPQ. Just a few candidates resorted to approximate values but still obtained the correct area.

(v)    There was a mixed response to this question. Some candidates quoted the general equation of an ellipse and then substituted, usually correctly, for the values of '$a$' and '$b$' using their results from part (i); a few candidates had already recognised the parametric coordinates of an ellipse in part (i) and used the equation there to find the coordinates of A and B. It was usually the more able candidates who eliminated $\theta$ from the parametric equations using the identity $\sin^2 \theta + \cos^2 \theta = 1$, and the weaker candidates who attempted to proceed by squaring and adding the equations as they stand obtaining $x^2 + y^2 = 16 \cos^2 \theta + 9 \sin^2 \theta$. Just a few candidates felt that it was sufficient to write $\theta = \cos^{-1} x/4$, and hence $y = 3 \sin(\cos^{-1} x/4)$.

(i) $(4,0), (0,3)$;   (ii) $2\sqrt{2}, 3\sqrt{2}/2$;   (iv) 12 sq. units;   (v) $x^2/16 + y^2/9 = 1$.

## Question 3 (Partial fractions, integration and differential equations)

(i)    Most candidates gave the correct equation although just a few did not answer this part.

(ii)    The partial fractions were found correctly by almost all the candidates.

(iii)    Again, almost all candidates wrote down the correct integral and limits and used the partial fractions to enable them to integrate, but there were two common errors.
$$\int \frac{1}{2x} + \frac{1}{2-x} \ dx = 2 \ln x - 2 \ln (2-x) \text{ or } \frac{1}{2} \ln x + \frac{1}{2} \ln(2-x)$$
Most candidates made correct substitutions into their integrals.

(iii)    The above errors were usually repeated in solving the differential equation after candidates had separated the variables correctly. Also, very many candidates dealt correctly with the combination of $\ln x$ and $\ln(2-x)$ and with $\dfrac{1}{2} \ln \dfrac{x}{2-x} = \ln \left( \dfrac{x}{2-x} \right)^{1/2}$. However, those candidates who delayed finding the value of the arbitrary constant until this stage often wrote
$$\ln z = \ln \left( \frac{x}{2-x} \right)^{1/2} + c \Rightarrow z = \left( \frac{x}{2-x} \right)^{1/2} + e^c.$$

(i) $x = 2$;   (ii) $\dfrac{1}{x(2-x)} = \dfrac{1}{2x} + \dfrac{1}{2(2-x)}$, $\dfrac{1}{2} \ln x$.

## Question 4. Vectors.

This question as a whole was very well done by the majority of candidates.

(i)    Candidates who dealt separately with the two lines almost always found the correct values for $\lambda$ and $\mu$ and checked that their values satisfied the equations from each of the coordinates. Candidates using the fact that if P lies on both lines then it is the point of intersection, usually solved the simultaneous equations $8 + 3\lambda = 3 + \mu$, and, $8 + 4\lambda = -1 -\mu$, and only had to check their values of $\lambda$ and $\mu$ in one other equation. A few candidates solved just the one equation, $3 + 2\mu = 1$, and failed to find the value of $\lambda$.

8

(ii)   This question was done very well except that a surprising number of candidates gave the obtuse angle between the lines. A small number used the wrong vectors, $\begin{pmatrix} 1 \\ 8 \\ 8 \end{pmatrix}$ and $\begin{pmatrix} 3 \\ 3 \\ -1 \end{pmatrix}$.

(iii)  Also very well done. Just a few candidates interchanged the position vector and the direction vector in their equation of the line.

(iv)   Candidates were confident in finding the intersection of the line and the plane and most used their point of intersection to find the perpendicular distance required. A few candidates used the formula for the distance of a point from a plane to do the last part.

## Section B.  Comprehension.

The performance of candidates on the comprehension was good, especially in questions 1, 2 and 3. There were a few numerical or sign errors in calculating the missing values in the table and some graphs were not very well drawn with straight sections instead of smooth curves. Occasionally candidates failed to get their graphs to cross at the points $(0, 1.7)$ and $(0, -1.7)$.

In question 3 (a) small number of candidates confused Jupiter with Mars and wrote the angle $t/2$ instead of $t/12$ and there were occasional slips of cos for sin or vice-versa. Also an occasional error in the radius 778.

Question 4 was not well done, many candidates giving the Day numbers as 15, 45 and 75 instead of 60, 180 and 300. In addition, although the relative positions of the Earth, the Sun and Mercury were often shown in the correct order on a straight line the answer would have been more convincing if the line had been shown at an angle of 60° to an initial line.

Question 5. A fairly small number of candidates showed clearly that they understood the diagram of the motion of the Sun and Mars relative to the Earth and gave excellent answers to this question. The majority of candidates appeared to be confused, many by lines 57-59 in the insert. Candidates often referred to this statement and came to the wrong conclusion, that the Sun and Mars could not collide because, when Mars was at the point of intersection the Sun was on the other side of the Earth. Other candidates said that the Sun and Mars appeared from Earth to be in line but were in fact far apart, whilst others said that 'things were different in three dimensions'. A considerable number of candidates avoided an explanation of the intersection of the apparent orbits by stating simply, and correctly, that the Sun and Mars could not collide because Mars was in an orbit round the Sun.