Name:	Class:	Class Register Number:

CHUNG CHENG HIGH SCHOOL (MAIN)

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PRELIMINARY EXAMINATION 2023

SECONDARY 4

ADDITIONAL MATHEMATICS 4049/01

Paper 1 **Thursday 24 August 2023**

2 hours 15 minutes

MARKS SCHEME

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Mathematical Formulae

1. ALGEBRA

Quadratic Equation

For the equation $ax^2 + bx + c = 0$,

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Binomial expansion

$$(a+b)^n = a^n + \binom{n}{1}a^{n-1}b + \binom{n}{2}a^{n-2}b^2 + \ldots + \binom{n}{r}a^{n-r}b^r + \ldots + b^n,$$

where n is a positive integer and $\binom{n}{r} = \frac{n!}{r!(n-r)!} = \frac{n(n-1)\ldots(n-r+1)}{r!}$.

2. TRIGONOMETRY

Identities

$$\sin^2 A + \cos^2 A = 1$$

$$\sec^2 A = 1 + \tan^2 A$$

$$\operatorname{cosec}^2 A = 1 + \cot^2 A$$

$$\sin(A \pm B) = \sin A \cos B \pm \cos A \sin B$$

$$\cos(A \pm B) = \cos A \cos B \mp \sin A \sin B$$

$$\tan(A \pm B) = \frac{\tan A \pm \tan B}{1 \mp \tan A \tan B}$$

$$\sin 2A = 2 \sin A \cos A$$

$$\cos 2A = \cos^2 A - \sin^2 A = 2\cos^2 A - 1 = 1 - 2\sin^2 A$$

$$\tan 2A = \frac{2\tan A}{1 - \tan^2 A}$$

Formulae for ΔABC

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$

$$a^2 = b^2 + c^2 - 2bc\cos A$$

$$\Delta = \frac{1}{2}ab\sin C$$

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1 The points R and S have coordinates $\left(\sqrt{3}, 2\sqrt{3}\right)$ and $\left(\sqrt{5}, 4\sqrt{5}\right)$ respectively. Show that the gradient of RS can be expressed in the form $a + b\sqrt{15}$, where a and b are integers to be found.

[4]

Gradient of $RS = \dfrac{4\sqrt{5}-2\sqrt{3}}{\sqrt{5}-\sqrt{3}} \times \dfrac{\sqrt{5}+\sqrt{3}}{\sqrt{5}+\sqrt{3}}$	B1 – $\dfrac{4\sqrt{5}-2\sqrt{3}}{\sqrt{5}-\sqrt{3}}$
$= \dfrac{\left(4\sqrt{5}-2\sqrt{3}\right)\left(\sqrt{5}+\sqrt{3}\right)}{\left(\sqrt{5}\right)^2-\left(\sqrt{3}\right)^2}$	M1 – $\surd$ $\dfrac{\sqrt{5}+\sqrt{3}}{\sqrt{5}+\sqrt{3}}$
$= \dfrac{20-4\sqrt{15}-2\sqrt{15}-6}{2}$	M1 – either numerator or denominator expanded correctly
$= \dfrac{14-6\sqrt{15}}{2}$	
$= \dfrac{2\left(7-3\sqrt{15}\right)}{2}$	
$= 7-3\sqrt{15}$	
$a = 7,\ b = -3$	A1

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2 Given that $\cos\theta = p$ and that θ is acute, express in terms of p,

(a) $\sin\theta$, [1]

$\sqrt{1-p^2}$ B1

(b) $\tan(90° - \theta)$, [2]

$= \dfrac{1}{\tan\theta}$

$= \dfrac{1}{\frac{\sqrt{1-p^2}}{p}}$ M1 – $\dfrac{1}{\text{their } \tan\theta}$

$= \dfrac{p}{\sqrt{1-p^2}}$ A1

(c) $\cos 2\theta$. [2]

$\cos 2\theta = 1 - 2\sin^2\theta$

$= 1 - 2\left(\sqrt{1-p^2}\right)^2$ M1 – uses any $\cos 2\theta$ formula correctly

$= 1 - 2(1-p^2)$

$= 1 - 2 + 2p^2$

$= 2p^2 - 1$ A1

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3 Express $\frac{12x^2+32x+31}{(2x-1)(x+2)^2}$ in partial fractions. [5]

$\frac{12x^2+32x+31}{(2x-1)(x+2)^2} = \frac{A}{2x-1}+\frac{B}{x+2}+\frac{C}{(x+2)^2}$

M1 – realising the form of partial fractions

$12x^2+32x+31 = A(x+2)^2+B(2x-1)(x+2)+C(2x-1)$

M1 – realising the need to eliminate the denominator

let $x=\frac{1}{2}$,

$50=\frac{25}{4}A$

$A=8$

let $x=-2$,

$15=-5C$

$C=-3$

let $x=0$,

$31=4A-2B-C$

$31=32-2B+3$

$2B=4$

$B=2$

$A=8,\ B=2,\ C=-3$

A1, A1, A1 – do not award last A1 if not expressed in partial fractions

$\frac{12x^2+32x+31}{(2x-1)(x+2)^2} = \frac{8}{2x-1}+\frac{2}{x+2}-\frac{3}{(x+2)^2}$

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4 The expression $ax^3 + bx^2 + b$ leaves a remainder of R when divided by $(x+1)$ and a remainder of $5R-2$ when divided by $(x+2)$.

(a) Show that $b = \frac{2-3a}{5}$. [4]

when $x = -1$,	
$a(-1)^3 + b(-1)^2 + b = R$	M1 – realises $f(-1) = R$
$-a + 2b = R$ --- (1)	
when $x = -2$,	
$a(-2)^3 + b(-2)^2 + b = 5R - 2$	M1 – realises $f(-2) = 5R - 2$
$-8a + 5b = 5R - 2$ --- (2)	
sub (1) into (2),	
$-8a + 5b = 5(-a + 2b) - 2$	DM1 – award only if both M1 above is achieved
$-8a + 5b = -5a + 10b - 2$	
$10b - 5b = -8a + 5a + 2$	
$5b = -3a + 2$	A1
$b = \frac{2-3a}{5}$ (shown)	AG

(b) Given further that $ab = -8$ and $a > b$, find the value of a and of b. [3]

$ab = -8$	
$b = \frac{-8}{a}$	
$\frac{-8}{a} = \frac{-3a+2}{5}$	M1 – allow slips only for LHS
$-40 = -3a^2 + 2a$	
$3a^2 - 2a - 40 = 0$	
$(3a+10)(a-4) = 0$	
$a = -\frac{10}{3}$ or $a = 4$	
$b = 2.4$ $b = -2$	√M1 – finding 'b'
(reject)	
$\therefore a = 4,\ b = -2$	A1

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(c) Using the values of a and b found in **part (b)**, explain why the equation $ax^3 + bx^2 + b = 0$ has only one real root and state its value. [4]

$4x^3 - 2x^2 - 2 = 0$ $2x^3 - x^2 - 1 = 0$ when $x = 1$, $2(1)^3 - 1^2 - 1 = 0$ $\therefore$ By factor theorem, $(x-1)$ is a factor.	B1 - factor
$(x-1)(2x^2 + cx + 1) = 0$ by comparing x^2 terms, $-2 + c = -1$ $c = 1$ $(x-1)(2x^2 + x + 1) = 0$	M1 – correct method to find quadratic (division or inspection)
For $2x^2 + x + 1 = 0$, discriminant $= 1^2 - 4(2)(1) = -7 < 0$ $\therefore 2x^2 + x + 1 = 0$ has no real roots. $4x^3 - 2x^2 - 2 = 0$ has only 1 real root of $x = 1$.	M1 – realising the need to find discriminant / solve quadratic equation A1 – no real roots + $x = 1$

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5 Find the coordinates of the stationary points of the curve $y = \dfrac{(x-3)^2}{x}$ and determine the nature of each stationary point. [7]

$y = \dfrac{(x-3)^2}{x}$

$= \dfrac{x^2 - 6x + 9}{x}$

$= x - 6 + \dfrac{9}{x}$

$= x - 6 + 9x^{-1}$

$\dfrac{dy}{dx} = 1 - 9x^{-2}$ — B1

$= 1 - \dfrac{9}{x^2}$

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

$1 - \dfrac{9}{x^2} = 0$ — M1 – sets $\dfrac{dy}{dx}$ to 0

$\dfrac{9}{x^2} = 1$

$x^2 = 9$

$x = 3$ or -3 — A1 – for (3,0)

$y = 0$ or -12 — A1 – for (-3, -12)

$\dfrac{d^2y}{dx^2} = 18x^{-3}$ — M1 – their 2nd derivative or use of 1st derivative test

$= \dfrac{18}{x^3}$

At $(3,0)$,

$\dfrac{d^2y}{dx^2} = \dfrac{18}{3^3} = \dfrac{2}{3} > 0$

$\therefore (3,0)$ is a minimum point — A1

At $(-3,-12)$,

$\dfrac{d^2y}{dx^2} = \dfrac{18}{(-3)^3} = -\dfrac{2}{3} < 0$

$\therefore (-3,-12)$ is a maximum point — A1

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6 The height above ground, h metres, of a ball, released by a machine can be modelled by the equation $h = -0.2x^2 + 6x + 3$ where x is the horizontal distance travelled by the ball in metres.

(a) State the height above ground at which the ball is released. [1]

3 metres

(b) Express $h = -0.2x^2 + 6x + 3$ in the form $a(x-b)^2 + c$, where a, b and c are constants to be found. [2]

$h = -0.2\left(x^2 - 30x\right) + 3$

$= -0.2\left(x^2 - 30x + 15^2 - 15^2\right) + 3$

$= -0.2\left[(x-15)^2 - 225\right] + 3$

$= -0.2(x-15)^2 + 48$

B2, 1 : –1 for each error

(c) Using your result from **(b)**, explain why the height of the ball can never be more than 48 metres. [2]

For $-0.2(x-15)^2 + 48$,

$(x-15)^2 \geq 0$,

$-0.2(x-15)^2 \leq 0$

$-0.2(x-15)^2 + 48 \leq 48$

Since the ball reaches a maximum height of 48 m, it will never reach a height of more than 48 m.

√ M1 – their square term

A1

(d) Hence, explain if this machine is safe for use in an indoor stadium with a ceiling height of 45 metres. [1]

Since the ball can reach a maximum height of 48m which exceeds the ceiling height of 45 m, this machine is not safe for use in the indoor stadium.

B1 – to have comparison of maximum height with ceiling height.

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7 **(a)** Solve the equation $3^x\left(18+3^x\right)=40$. [3]

$$3^x\left(18+3^x\right)=40$$
$$\left(3^x\right)^2+18\left(3^x\right)-40=0$$

Let $y = 3^x$.

$$y^2+18y-40=0$$
$$(y+20)(y-2)=0$$
$$y=-20 \quad \text{or} \quad y=2$$

M1 – solving of quadratic equation

$3^x=-20$ (rej. $\because 3^x>0$) or

$$3^x=2$$
$$\ln 3^x=\ln 2$$
$$x\ln 3=\ln 2$$
$$x=\frac{\ln 2}{\ln 3}$$
$$=0.631 \text{ (3 sig. fig.)}$$

M1 – taking ln

A1

(b) Solve the equation $\log_{\sqrt{2}} y=3+\log_2(y+6)$. [5]

$$\log_{\sqrt{2}} y=3+\log_2(y+6)$$
$$\log_{\sqrt{2}} y-\log_2(y+6)=3$$
$$\frac{\log_2 y}{\log_2\sqrt{2}}-\log_2(y+6)=3$$

B1 – change of base law

$$\frac{\log_2 y}{\frac{1}{2}}-\log_2(y+6)=3$$

M1 – power law

$$2\log_2 y-\log_2(y+6)=3$$
$$\log_2\left(\frac{y^2}{y+6}\right)=3$$

M1 – quotient law

Comparing,

$$\frac{y^2}{y+6}=3$$
$$y^2=3y+18$$
$$y^2-3y-18=0$$
$$(y-6)(y+3)=0$$
$$y=6 \quad \text{or} \quad -3 \text{ (rej. } \therefore y>0)$$

M1 – removal of log/comparing

A1

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Continuation of working space for question 7(b)

(c) In order to obtain a graphical solution of the equation $x = 2\ln\left(4 - \frac{3x}{2}\right)$, a suitable straight line can be drawn on the same set of axes as the graph of $y = 4 - e^{\frac{x}{2}}$. Make $e^{\frac{x}{2}}$ the subject of $x = 2\ln\left(4 - \frac{3x}{2}\right)$ and hence find the equation of this line. [3]

$x = 2\ln\left(4 - \frac{3x}{2}\right)$	
$\frac{x}{2} = \ln\left(4 - \frac{3x}{2}\right)$	M1 – attempt to make $\ln\left(4 - \frac{3x}{2}\right)$ the subject
$e^{\frac{x}{2}} = 4 - \frac{3x}{2}$	A1
$\frac{3x}{2} = 4 - e^{\frac{x}{2}}$	
Equation of line: $y = \frac{3x}{2}$	B1

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8 A curve has the equation $y = \dfrac{x^2 - x + 1}{5x - 5}$, $x \neq 1$.

(a) Show that $\dfrac{dy}{dx} = \dfrac{x^2 - 2x}{5(x-1)^2}$. [3]

$$\frac{dy}{dx} = \frac{(5x-5)(2x-1) - (x^2 - x + 1)(5)}{(5x-5)^2}$$

$$= \frac{10x^2 - 5x - 10x + 5 - 5x^2 + 5x - 5}{[5(x-1)]^2}$$

$$= \frac{5x^2 - 10x}{5^2(x-1)^2}$$

$$= \frac{5(x^2 - 2x)}{25(x-1)^2}$$

$$= \frac{x^2 - 2x}{5(x-1)^2} \text{ (shown)}$$

M1 – quotient rule performed correctly, allow for numerical slips

B1 – for $5^2(x-1)^2 / 25(x-1)^2$

A1 – factorisation must be seen

AG

(b) Explain why the curve is increasing for $x > 2$. [3]

Alternative solution

Where the curve is increasing,

$\dfrac{dy}{dx} > 0,$

$\dfrac{x^2 - 2x}{5(x-1)^2} > 0$

Since $5(x-1)^2 > 0,$ for all real values of x,

$x^2 - 2x > 0$

$x(x-2) > 0$

$x < 0$ or $x > 2$

$\therefore$ for $x > 2,$ the curve is always increasing.

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

$x > 2,\ x - 2 > 0$

$x(x-2) > 0$

since $(x-1)^2 > 0$

$\dfrac{x^2 - 2x}{5(x-1)^2} > 0$

Since $\dfrac{dy}{dx} > 0,$ the curve is always increasing.

B1 – $x > 2,\ x - 2 > 0,\ x(x-2) > 0$

B1 – $(x-1)^2 > 0$

B1 – $\dfrac{x^2 - 2x}{5(x-1)^2} > 0$ + conclusion of curve is always increasing. Award only if B1,B1 has been achieved.

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9 **(a)** Given that $\frac{\cos(\alpha+\beta)}{\cos(\alpha-\beta)}=\frac{3}{4}$, prove that $\cos\alpha\cos\beta=7\sin\alpha\sin\beta$. [2]

$4[\cos\alpha\cos\beta-\sin\alpha\sin\beta]=3[\cos\alpha\cos\beta+\sin\alpha\sin\beta]$
$4\cos\alpha\cos\beta-4\sin\alpha\sin\beta=3\cos\alpha\cos\beta+3\sin\alpha\sin\beta$
$4\cos\alpha\cos\beta-3\cos\alpha\cos\beta=4\sin\alpha\sin\beta+3\sin\alpha\sin\beta$
$\cos\alpha\cos\beta=7\sin\alpha\sin\beta$ (shown)

M1 – attempt at addition formula

A1
AG

(b) Hence, deduce the relationship between $\tan\alpha$ and $\tan\beta$. [2]

$\cos\alpha\cos\beta=7\sin\alpha\sin\beta$
$\frac{1}{7}=\frac{\sin\alpha\sin\beta}{\cos\alpha\cos\beta}$
$\tan\alpha\tan\beta=\frac{1}{7}$ or $\frac{1}{\tan\beta}=7\tan\alpha$

M1 – realises the need to divide

A1

(c) Given further that $\alpha+\beta=45°$, calculate the value of $\tan\alpha+\tan\beta$. [3]

$\tan(\alpha+\beta)=\frac{\tan\alpha+\tan\beta}{1-\tan\alpha\tan\beta}$
$\tan 45°=\frac{\tan\alpha+\tan\beta}{1-\frac{1}{7}}$
$1=\frac{\tan\alpha+\tan\beta}{\frac{6}{7}}$
$\tan\alpha+\tan\beta=\frac{6}{7}$

M1 – $\tan 45°$ or realises the need for $\frac{\tan\alpha+\tan\beta}{1-\tan\alpha\tan\beta}$

M1- their $\tan\alpha\tan\beta$

A1

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10 A circle, whose equation is $x^2 + y^2 - 10x - 8y + 16 = 0$, has centre C and radius r.

(a) Find the coordinates of C and the value of r. [3]

$-2a = -10$
$a = 5$
$-2b = -8$
$b = 4$
$a^2 + b^2 - r^2 = 16$
$r^2 = 5^2 + 4^2 - 16$
$r = 5$
$\therefore C(5,4)$ and r is 5 units.

M1 – their a and b

B1 – (5,4), A1 – 5 units

Alternative Solution

$x^2 + y^2 - 10x - 8y + 16 = 0$
$x^2 - 10x + 5^2 - 5^2 + y^2 - 8y + 4^2 - 4^2 + 16 = 0$
$(x-5)^2 + (y-4)^2 = 25 + 16 - 16$
$(x-5)^2 + (y-4)^2 = 5^2$
$C(5,4)$ and $r = 5$ units.

M1 – attempt to complete square

B1 – (5,4), A1 – 5 units

(b) Explain whether the point $(9,2)$ lies inside or outside the circle. [2]

Distance from $(9,2)$ to C
$= \sqrt{(9-5)^2 + (4-2)^2}$
$= \sqrt{20} < 5$ (radius)
$\therefore (9,2)$ lies inside the circle.

M1 – realises the need to find distance from (9,2) to C

A1 – need to indicate < 5 (radius) and therefore inside the circle

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The line $4y = 3x + 1$ meets the circle at the points *P* and *T*, and the *x*-axis at *S*.
T lies between *P* and *S*.

(c) Without finding the coordinates of *P* and of *T*, find the length *TS*. [4]

At S, $y = 0$
$3x + 1 = 0$
$x = -\frac{1}{3}$
$S\left(-\frac{1}{3}, 0\right)$

M1 – realises that $y = 0$ for S

Subst $x = 5$ into $4y = 3x + 1$,
$4y = 3(5) + 1$
$y = \frac{16}{4} = 4$
$\therefore (5, 4)$ lies on the line $4y = 3x + 1$

B1 – shows centre lies on line

Distance from C to S
$= \sqrt{\left(5 - \left(-\frac{1}{3}\right)\right)^2 + 4^2}$
$= 6\frac{2}{3}$ units

M1 – distance from their C to S

$\therefore TS = 6\frac{2}{3} - 5$
$= 1\frac{2}{3}$ units

A1

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11 The table shows, to 1 decimal place, the mass, m of a radioactive substance, in grams, after t days.

t	5	10	15	20	25
m	57.7	37.0	23.7	15.2	9.7

(a) On the grid opposite, plot $\ln m$ against t and draw a straight line graph. [2]

(b) Find the gradient of your straight line and hence express m in the form $m_0 e^{kt}$, where m_0 and k are constants. [4]

gradient $= -\frac{2.25}{25} = -0.09$	B1 – finds gradient correctly
$\ln m = -0.09t + 4.5$	M1 – finds $\ln m = 'm't + c$ with their gradient + y-intercept
$m = e^{-0.09t+4.5}$	
$m = e^{-0.09t} \bullet e^{4.5}$	
$m = 90.0e^{-0.09t}$	A1,A1

The half-life of a radioactive substance is the length of time it takes for half of the substance to decay.

(c) In order to determine the half-life of the radioactive substance, a suitable straight line can be drawn on the same set of axes as your graph. Find the equation of this line and hence determine the half-life of the radioactive substance. [3]

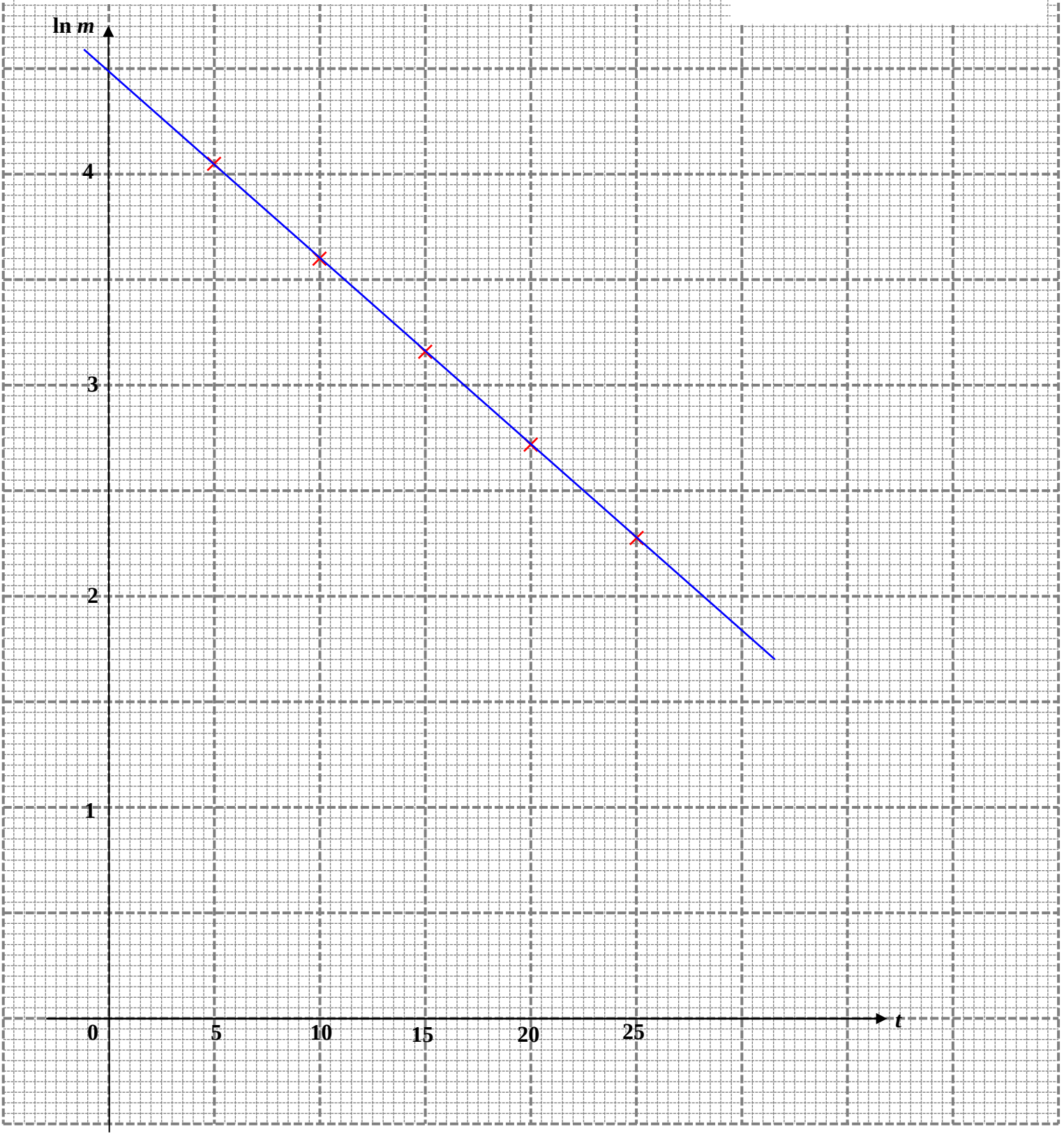
$m = 90.0e^{-0.09t}$	
when $t = 0$,	
$m = 90.0$ (inital mass)	M1 – attempt to find original mass
half of original mass $= 45$	
$\ln 45 = 3.80.$	
line to be drawn :	
$y = 3.8$	A1
Half-life = 7.75 days	A1

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t	5	10	15	20	25
ln m	4.055	3.61	3.16	2.72	2.27

P1 – at least 3 points

P2 – straight line drawn with all points plotted correctly



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12 A particle travels in a straight line so that its velocity, v cm/s, t seconds after passing through a fixed point O, is given by $v = t^2 - kt + 5$, where k is a constant. The particle first comes to an instantaneous rest at the point P and then at the point Q.

(a) Given that the particle reaches a minimum velocity at $t = 3$, show that $k = 6$. [2]

$v = t^2 - kt + 6$

$= \left(t - \frac{k}{2}\right)^2 + 5 - \frac{k^2}{4}$ B1

minimum velocity occurs

when $t - \frac{k}{2} = 0$

$3 - \frac{k}{2} = 0$ √M1

$6 - k = 0$

$k = 6$ (shown)

$v = t^2 - kt + 6$

$\frac{dv}{dt} = 2t - k$

when $t = 3$, $\frac{dv}{dt} = 0$

$2(3) - k = 0$

$6 - k = 0$

$k = 6$ (shown)

B1

√M1 – recognises $\frac{dv}{dt} = 0$ when $t = 3$

AG

(b) Find the distance PQ. [6]

At P and Q, $v = 0$

$t^2 - 6t + 5 = 0$

$(t-1)(t-5) = 0$

$t = 1$ or $t = 5$

M1 – equates v to 0

A1

$s = \frac{1}{3}t^3 - 3t^2 + 5t + c$

when $t = 0, s = 0, \ \therefore c = 0$

M1 – realises the need to integrate

A1

$s = \frac{1}{3}t^3 - 3t^2 + 5t$

when $t = 1, s = 2\frac{1}{3}$

when $t = 5, s = -8\frac{1}{3}$

M1 – s at their $t = 1$ or $t = 5$

Distance $PQ = 2\frac{1}{3} + 8\frac{1}{3}$

$= 10\frac{2}{3}$ m

A1

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(c) With working clearly shown, explain whether the particle will pass by O again, after the first 7 seconds.

[2]

At $t = 7,\ s = 2\frac{1}{3},\ v = 12$

Since $s > 0,\ v > 0$ and there are no more turning points after $t = 5,$ the particle will not return to O after 7 seconds.

M1 – finds s or v at $t = 7$

A1 - explains no turning points particle will not return to O

Alternative solution

$$\frac{1}{3}t^3 - 3t^2 + 5t = 0$$

$$t^3 - 9t^2 + 15t = 0$$

$$t\left(t^2 - 9t + 15\right) = 0$$

$$t = 0 \text{ or } t = \frac{9 \pm \sqrt{(-9)^2 - 4(1)(15)}}{2}$$

$$= 6.79 \quad \text{or} \quad 2.21$$

Since the last time that the particle is at O is 6.79s, which is before 7 seconds, the particle will not pass by O again after 7 seconds.

M1 – Attempt at solution for $s = 0$

A1 – explains that last time that the particle is at O is 6.79s , which is before 7s and hence does not return to O

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