

Question 1

a. Outcomes Assessed: PE5, HE4

Marking Guidelines

Criteria	Marks
• Applies the product rule with correct derivative of $\tan^{-1}x$	1
• Simplifies resulting expression	1

Answer

$$\frac{d}{dx}(1+x^2)\tan^{-1}x = 2x\tan^{-1}x + (1+x^2)\frac{1}{1+x^2} = 1 + 2x\tan^{-1}x$$

b. Outcomes Assessed: PE3

Marking Guidelines

Criteria	Marks
• uses the remainder theorem to obtain an equation for a	1
• solves the equation to evaluate a .	1

Answer

$$P(1) = P(2) \Rightarrow a+2 = 2a+9 \quad \therefore a = -7$$

c. Outcomes Assessed: (i) H5 (ii) P4

Marking Guidelines

Criteria	Marks
i. • writes the expression for $\tan 45^\circ$ in terms of the gradients of the lines	1
• obtains the required equation by putting $\tan 45^\circ = 1$ and rearranging	1
ii. • finds one of the values of m with the corresponding line	1
• finds the second value of m and the equation of the second line	1

Answer

$$i. \quad \left| \frac{m-2}{1+2m} \right| = \tan 45^\circ = 1$$

$$\therefore |m-2| = |1+2m|$$

$$ii. \quad m-2 = 1+2m \quad \text{or} \quad m-2 = -(1+2m)$$

$$-3 = m$$

$$m-2 = -1-2m$$

$$3m = 1$$

$$\therefore m = -3 \quad \text{or} \quad m = \frac{1}{3}$$

The required lines are $y = -3x$ and $y = \frac{1}{3}x$

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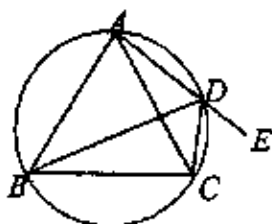
d. Outcomes Assessed: (i) PE3 (ii) PE2, PE3

Marking Guidelines

Criteria	Marks
i. •	0
ii. • gives suitable reason referring to appropriate property of cyclic quadrilateral	1
iii. • explains why $\angle BDC = \angle BAC$	1
• explains why $\angle BAC = \angle ABC$	1
• uses these facts to make final deduction about DC	1

Answer

i.



ii. $\angle CDE = \angle ABC$ (exterior angle of cyclic quadrilateral ABCD is equal to the opposite interior angle).

iii. $\angle BDC = \angle BAC$ (\angle s subtended at circumference by same arc BC are equal)

$\angle BAC = \angle ABC$ (\angle s opposite equal sides BC and AC in $\triangle ABC$ are equal)

$\therefore \angle BDC = \angle ABC$

$\therefore \angle BDC = \angle CDE$ (both equal to $\angle ABC$)

$\therefore DC$ bisects $\angle BDE$.

Question 2

a. Outcomes Assessed: P4

Marking Guidelines

Criteria	Marks
• applies an appropriate formula or pattern for external division	1
• evaluates the coordinates of P.	1

Answer

$$\begin{array}{cc}
 A & B \\
 (-5, 6) & (1, 3) \\
 \swarrow & \searrow \\
 5 & -2 \\
 \hline
 \left(\frac{5+10}{5-2}, \frac{15-12}{5-2} \right) & \therefore P(5, 1)
 \end{array}$$

b. Outcomes Assessed: PE3

Marking Guidelines

Criteria	Marks
• expresses $\sum \frac{1}{\alpha}$ in terms of $\sum \alpha\beta$ and $\alpha\beta\gamma$.	1
• reads correct values of $\sum \alpha\beta$ and $\alpha\beta\gamma$ from coefficients to evaluate $\sum \frac{1}{\alpha}$	1

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Answer

$$2x^2 + 2x^2 + 4x + 1 = 0 \text{ has roots } \alpha, \beta, \gamma. \quad \therefore \frac{1}{\alpha} + \frac{1}{\beta} + \frac{1}{\gamma} = \frac{\beta\gamma + \gamma\alpha + \alpha\beta}{\alpha\beta\gamma} = \frac{\left(\frac{4}{2}\right)}{\left(-\frac{1}{2}\right)} = -4$$

c. Outcomes Assessed: (i) H5 (ii) H5

Marking Guidelines

Criteria	Marks
i. • identifies common ratio as $\cos 2x$ • applies condition for existence of limiting sum	1 1
ii. • writes expression for S in terms of $\sin 2x$ and $\cos 2x$ • uses appropriate trig. identities to simplify expression for S .	1 1

Answer

i. $r = \cos 2x, 0 < x < \frac{\pi}{2} \Rightarrow |r| < 1.$

Hence limiting sum S exists.

$$\text{ii. } S = \frac{\sin 2x}{1 - \cos 2x} \quad \therefore S = \frac{\cos x}{\sin x} = \cot x$$

$$= \frac{2 \sin x \cos x}{2 \sin^2 x}$$

d. Outcomes Assessed: (i) PE3, PE4 (ii) PE3

Marking Guidelines

Criteria	Marks
i. • finds $\frac{dy}{dx}$ to show that the tangent has gradient t • finds the equation of the tangent	1 1
ii. • finds x and y coordinates of M in terms of t • finds Cartesian equation of locus of M	1 1

Answer

i. $x = 2t \Rightarrow \frac{dx}{dt} = 2$

$$y = t^2 \Rightarrow \frac{dy}{dt} = 2t$$

$$\therefore \frac{dy}{dx} = \frac{2t}{2} = t$$

Tangent has gradient t and equation

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

$$y - t^2 = tx - 2t^2$$

$$tx - y - t^2 = 0$$

ii. at M , $tx - y - t^2 = 0$ and $y = -tx$

$$\therefore 2tx - t^2 = 0$$

$$2t\left(x - \frac{1}{2}t\right) = 0$$

If $t = 0$, P and M both lie at the origin.

Otherwise at M $x = \frac{1}{2}t$, $y = -\frac{1}{2}t^2$,

giving $y = -\frac{1}{2}(2x)^2$.

$$\therefore \text{locus of } M \text{ has equation } y = -2x^2.$$

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Question 3

a. Outcomes Assessed: (i) P4 (ii) P4

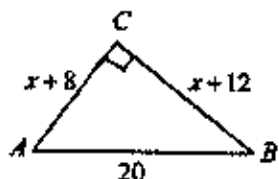
Marking Guidelines

Criteria	Marks
i. • uses Pythagoras to obtain an equation for x	1
• simplifies this equation by expanding squares and collecting like terms	1
ii. • factors this quadratic (or applies an alternative method)	1
• finds the radius of the circle with centre C .	1

Answer

When circles touch, the line joining centres passes through the point of contact, giving the sides of right triangle ABC as shown below

i.



$$\begin{aligned}(x+8)^2 + (x+12)^2 &= 20^2 \\ 2x^2 + 40x + 64 + 144 &= 400 \\ 2x^2 + 40x - 192 &= 0 \\ x^2 + 20x - 96 &= 0\end{aligned}$$

ii.

$$\begin{aligned}(x+24)(x-4) &= 0 \\ \therefore x > 0 \Rightarrow x &= 4 \\ \text{Circle with centre } C &\text{ has} \\ \text{radius } 4 \text{ cm.}\end{aligned}$$

b. Outcomes Assessed: (i) P3 (ii) HE6

Marking Guidelines

Criteria	Marks
i. • rearranges either LHS or RHS to establish result	1
ii. • transforms integral into form $2 \int \frac{u}{1+u} du$	1
• finds primitive in terms of u	1
• finds primitive in terms of x	1

Answer

i. $\frac{u}{1+u} = \frac{(1+u)-1}{1+u}$
 $= 1 - \frac{1}{1+u}$

ii. $u \geq 0$
 $x = u^2$
 $dx = 2u du$

$$\begin{aligned}\int \frac{1}{1+\sqrt{x}} dx &= \int \frac{1}{1+u} 2u du \\ &= 2 \int \frac{u}{1+u} du \\ &= 2 \int \left(1 - \frac{1}{1+u}\right) du \\ &= 2\{u - \ln(1+u)\} + c \\ &= 2\sqrt{x} - 2\ln(1+\sqrt{x}) + c\end{aligned}$$

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c. Outcomes Assessed: HE2

Marking Guidelines

Criteria	Marks
• shows the statement is true for $n = 3$	1
• shows that $5^{k+1} > 5(4^k + 3^k)$ if $S(k)$ is true	1
• completes the explanation that $S(k)$ true implies $S(k+1)$ true	1
• makes final statements to complete the Mathematical Induction	1

Answer

Let $S(n)$ be the statement $5^n > 4^n + 3^n$, $n = 3, 4, 5, \dots$

Consider $S(3)$: $5^3 = 125$, $4^3 + 3^3 = 64 + 27 = 91$. Hence $S(3)$ is true.

If $S(k)$ is true: $5^k > 4^k + 3^k$ **

Consider $S(k+1)$: $5^{k+1} = 5 \cdot 5^k$

$$> 5(4^k + 3^k) \text{ if } S(k) \text{ is true, using **}$$

$$= 5 \cdot 4^k + 5 \cdot 3^k$$

$$> 4 \cdot 4^k + 3 \cdot 3^k$$

$$= 4^{k+1} + 3^{k+1}$$

Hence if $S(k)$ is true, then $S(k+1)$ is true. But $S(3)$ is true, hence $S(4)$ is true and then $S(5)$ is true and so on. Hence by Mathematical Induction $5^n > 4^n + 3^n$ for all integers $n \geq 3$.

Question 4

a. Outcomes Assessed: PE3

Marking Guidelines

Criteria	Marks
• writes an expression for the general term in the expansion	1
• identifies the term independent of x	1
• calculates the term independent of x	1

Answer

$$\text{General term is } {}^{15}C_r \left(-\frac{2}{x^3}\right)^r x^{15-r} = {}^{15}C_r (-2)^r x^{15-3r}, \quad r = 0, 1, 2, \dots, 15$$

$$\text{Constant term has } 15 - 3r = 0 \Rightarrow r = 5$$

$$\therefore \text{term independent of } x \text{ is } {}^{15}C_5 (-2)^5 = -96\,096.$$

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b. Outcomes Assessed: (i) HE3 (ii) H3

Marking Guidelines

Criteria	Marks
i. • uses given information to show one of $A=100$ or $A+B=500$	1
• shows the second result about A, B and deduces the values of A and B	1
ii. • obtains $t \geq 2 \ln 40$	1
• calculates the time to nearest month	1

Answer

i. $N = A + Be^{-0.5t}$

$t = 0, N = 500 \Rightarrow A + B = 500$

$t \rightarrow \infty, N = 100 \Rightarrow A + 0 = 100$

$\therefore A = 100, B = 400$

ii. $N \leq 110 \Rightarrow 100 + 400e^{-0.5t} \leq 110$

$400e^{-0.5t} \leq 10$

$e^{-0.5t} \leq \frac{1}{40}$

$e^{0.5t} \geq 40$

$\frac{1}{2}t \geq \ln 40$

$t \geq 2 \ln 40$

Population falls within 10 of limiting size
after $7.38 \text{ yrs} \approx 7 \text{ yrs } 5 \text{ months}$.

c. Outcomes Assessed: (i) PE3 (ii) PE3

Marking Guidelines

Criteria	Marks
i. • shows $f(0), f(1)$ have opposite signs	1
• notes continuity of f to justify deduction.	1
ii. • obtains expression for α by substitution into Newton's formula	1
• calculates at least one of $f(0.7), f'(0.7)$ correctly	1
• approximates α to 2 decimal places	1

Answer

i. $f(x) = x - \cos x$

 f is a continuous function and

$f(0) = 0 - 1 < 0$

$f(1) = 1 - \cos 1 > 0$

$\therefore f(\alpha) = 0$ for some α such that $0 < \alpha < 1$.

ii. $f'(x) = 1 + \sin x$

$$\alpha = 0.7 - \frac{0.7 - \cos 0.7}{1 + \sin 0.7}$$

$$= 0.7 - \frac{-0.065}{1.644}$$

$$= 0.74$$

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Question 5

a. Outcomes Assessed (i) HE3 (ii) HE3:

Marking Guidelines

Criteria	Marks
i. • writes appropriate expression for binomial probability	1
ii. • interprets <i>at most</i> as either sum or complement of appropriate binomial probabilities	1
• calculates the probability in fraction or decimal form	1

Answer

Binomial distribution: $n = 4$, $p = \frac{2}{3}$, $q = \frac{1}{3}$

i. ${}^4C_3 \left(\frac{2}{3}\right)^3 \left(\frac{1}{3}\right) = \frac{96}{625}$ ii. $1 - {}^4C_1 \left(\frac{2}{3}\right)^4 = 1 - \frac{16}{625} = \frac{609}{625}$

b. Outcomes Assessed: (i) P3 (ii) HE 5

Marking Guidelines

Criteria	Marks
i. • obtains required expression for S in terms of h	1
ii. • writes expression for $\frac{dS}{dt}$ in terms of $\frac{dh}{dt}$	1
• evaluates $\frac{dS}{dt}$ when $h = 2$	1
• interprets negative value and provides appropriate units	1

Answer

i. The surface of the water is a circle with radius x when the depth is y , where $x^2 = 4 - y$.

When the depth is h , $S = \pi x^2 = \pi(4 - h)$

ii. $\therefore \frac{dS}{dt} = -\pi \frac{dh}{dt} = -\pi \frac{10}{\pi(4 - h)} = -5$ when $h = 2$

When depth is 2 cm, surface area of the water is decreasing at a rate of $5\text{cm}^2\text{s}^{-1}$.

c. Outcomes Assessed: (i) H5 (ii) H5 (iii) PE3

Marking Guidelines

Criteria	Marks
i. • finds $f''(x)$ and notes $f''(x) > 0$ for all x	1
ii. • finds coordinates of stationary point	1
• states nature of stationary point	1
iii. • deduces that $f(x) \geq 1$ for all x	1
• uses this result to deduce $e^x \geq x + 1$ for all x	1

Answer

i. $f(x) = e^x - x$

$f'(x) = e^x - 1$

$f''(x) = e^x$

$f''(x) > 0$ for all x , hence curve is concave up for all x .

ii. $f'(x) = 0 \Rightarrow e^x = 1 \therefore$ stationary point is $(0, 1)$

Since curve is concave up, $(0, 1)$ is a minimum turning point

iii. $f(x) \geq 1$ for all $x \Rightarrow e^x - x \geq 1$ for all x

$\therefore e^x \geq x + 1$ for all x .

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Question 6

a. Outcomes Assessed: (i) HE4 (ii) HE4 (iii) B8

Marking Guidelines

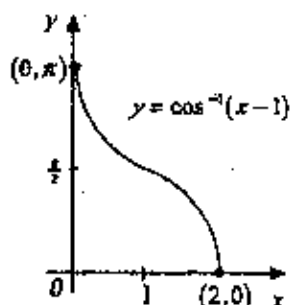
Criteria	Marks
i. • states domain of function	1
ii. • sketches curve with correct shape and position	1
• shows endpoints with correct coordinates	1
iii. • writes integral for V in terms of y	1
• finds primitive function	1
• evaluates V by substitution of correct limits	1

Answer

i. $f(x) = \cos^{-1}(x-1) \Rightarrow -1 \leq x-1 \leq 1$

\therefore Domain is $\{x: 0 \leq x \leq 2\}$

ii.



iii. $V = \pi \int_0^{\pi} x^2 dy$,

where $\cos y = x-1 \Rightarrow x = 1 + \cos y$.

$$\begin{aligned} \therefore V &= \pi \int_0^{\pi} (1 + \cos y)^2 dy \\ &= \pi \int_0^{\pi} (1 + 2\cos y + \cos^2 y) dy \\ &= \pi \int_0^{\pi} (1 + 2\cos y + \frac{1}{2}(1 + \cos 2y)) dy \\ &= \pi \int_0^{\pi} (\frac{3}{2} + 2\cos y + \frac{1}{2}\cos 2y) dy \\ &= \pi [\frac{3}{2}y + 2\sin y + \frac{1}{4}\sin 2y]_0^{\pi} \\ &= \pi (\frac{3}{2}\pi + 0 + 0) \end{aligned}$$

Volume is $\frac{3}{2}\pi^2$ cubic units.

b. Outcomes Assessed: (i) HE3 (ii) HE3 (iii) HE3

Marking Guidelines

Criteria	Marks
i. • expresses x in terms of $\cos 2t$	1
• expresses \dot{x} in required form	1
ii. • finds possible values for x	1
• states period of motion	1
iii. • finds smallest t for which $x = 0$	1
• finds initial x and deduces distance travelled	1

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Answer

$$\begin{aligned}
 \text{i. } x &= 4\cos^2 t - 2\sin^2 t \\
 &= 2(1 + \cos 2t) - (1 - \cos 2t) \\
 &= 1 + 3\cos 2t \\
 \dot{x} &= -6\sin 2t \\
 \ddot{x} &= -12\cos 2t \\
 &= -4(x-1) \\
 \ddot{x} &= -2^2(x-1)
 \end{aligned}$$

$$\begin{aligned}
 \text{ii. } -1 &\leq \cos 2t \leq 1 \\
 -3 &\leq 3\cos 2t \leq 3 \\
 -2 &\leq 1 + 3\cos 2t \leq 4 \\
 \therefore -2 &\leq x \leq 4
 \end{aligned}$$

Period of the motion is $\frac{2\pi}{n} = \pi$ s

$$\begin{aligned}
 \text{iii. } x = 0 &\Rightarrow \cos 2t = -\frac{1}{3} \\
 \text{Smallest such } t &\text{ is } \frac{1}{2}\cos^{-1}\left(-\frac{1}{3}\right) = 1.0
 \end{aligned}$$

Initially particle is at $x = 4$.

Hence particle first passes through O after 1.0 s when particle has travelled a distance of 4m.

Question 7

a. Outcomes Assessed: (i) HE5 (ii) HE5 (iii) HE5, HE7

Marking Guidelines

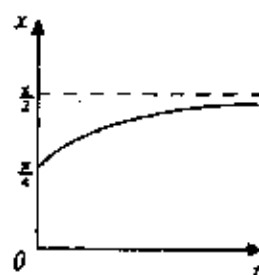
Criteria	Marks
i. • uses chain rule then simplifies using trig. identities	1
ii. • writes expression for $\frac{dt}{dx}$	1
• finds expression for t in terms of x , evaluating the constant of integration	1
• finds expression for x in terms of t	1
iii. • states limiting position	1
• sketches graph of x against t with correct shape, endpoint and asymptote	1

Answer

$$\begin{aligned}
 \text{i. } \frac{d}{dx} \ln(\tan x) &= \frac{\sec^2 x}{\tan x} \\
 &= \frac{1}{\cos^2 x} \frac{\cos x}{\sin x} \\
 &= \frac{1}{\sin x \cos x}
 \end{aligned}$$

$$\begin{aligned}
 \text{ii. } v &= \sin x \cos x \\
 \frac{dx}{dt} &= \sin x \cos x \\
 \frac{dt}{dx} &= \frac{1}{\sin x \cos x} \\
 t &= \ln(\tan x) + c \\
 t = 0, x = \frac{\pi}{4} &\Rightarrow c = 0 \\
 \therefore t &= \ln(\tan x) \\
 e^t &= \tan x \\
 x &= \tan^{-1}(e^t)
 \end{aligned}$$

iii. as $t \rightarrow \infty$, $x \rightarrow \frac{\pi}{2}$
 \therefore limiting position is $\frac{\pi}{2}$ metres to the right of O .

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b. Outcomes Assessed: (i) HE3 (ii) HE3 (iii) HE3
Marking Guidelines

Criteria	Marks
i. • writes horizontal and vertical displacements for particle projected from A	1
• writes horizontal and vertical displacements for particle projected from O	1
ii. • equates expressions for x and y to obtain equations (1) and (2) if particles collide	1
• solves simultaneously to find $\cos\theta$, $\sin\theta$ and t if collision occurs	1
iii. • obtains values for \dot{x} , \dot{y} for each particle for $t=1$ and $\theta = \tan^{-1}2$	1
• deduces that if particles collide, their velocities are perpendicular at that time	1

Answer

i. Particle projected from A :

horizontal displacement $x=10t$

vertical displacement $y=20-5t^2$

Particle projected from O :

horizontal displacement $x=10\sqrt{5}t\cos\theta$

vertical displacement $y=10\sqrt{5}t\sin\theta-5t^2$

ii. If the particles collide at some time t

$$10t = 10\sqrt{5}t\cos\theta \quad (1) \text{ and}$$

$$20 - 5t^2 = 10\sqrt{5}t\sin\theta - 5t^2$$

$$20 = 10\sqrt{5}t\sin\theta \quad (2)$$

$$\text{From (1), } \cos\theta = \frac{1}{\sqrt{5}} \therefore \sin\theta = \frac{2}{\sqrt{5}}$$

Substituting in (2) gives $t=1$

Hence the particles collide if $\theta = \tan^{-1}2$,
and in this case they collide after 1 s.

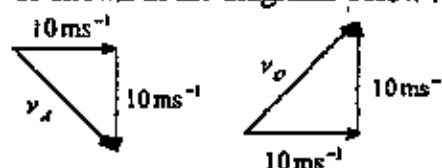
iii. If $\theta = \tan^{-1}2$, when $t=1$

the particle from A has $\dot{x}=10$ and $\dot{y}=-10$

the particle from O has $\dot{x}=10$ and $\dot{y}=20-10=10$

Hence the particles have velocities v_A and v_O

as shown in the diagrams below :



Hence if the particles collide, when they do so the particle from A is travelling in a direction 45° below the horizontal while the particle from O is travelling in a direction 45° above the horizontal, and their paths of motion are perpendicular to each other.

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