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Name: ....

Teacher:..

Pymble Ladies' College

HIGHER SCHOOL CERTIFICATE TRIAL EXAMINATION

2014

Mathematics Extension 1

General Instructions

- Reading time – 5 minutes.
- Working time – 2 hours.
- Write using pencil for Questions 1-10.
- Write using black or blue pen for Questions 11-14. Black pen is preferred.
- Board approved calculators may be used.
- A table of standard integrals is provided at the back of this paper.
- In Questions 11-14, show relevant mathematical reasoning and/or calculations.

Total Marks – 70

Section I Pages 1-4

10 marks

- Attempt all Questions 1-10
- Allow about 15 mins for this section

Section II Pages 5-11

60 marks

- Attempt Questions 11-14
- Allow about 1 hour 45 minutes for this section

Mark	**/70**
Highest Mark	**/70**
Rank	

Section I

10 marks
Attempt Questions 1-10
Allow about 15 minutes for this section.

Use the multiple choice answer sheet for Questions 1-10.

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1 The roots of the equation $x^3 - 5x^2 + 4 = 0$ are α, β and γ.

The value of $\alpha + \beta + \gamma$ and the value of $\alpha\beta\gamma$ are respectively.

(A) 5 and 4

(B) 5 and -4

(C) -5 and 4

(D) -5 and -4

2 Evaluate $\sin^{-1}\left(\sin\frac{4\pi}{3}\right)$.

(A) $\frac{4\pi}{3}$

(B) $\frac{\pi}{3}$

(C) $\frac{-2\pi}{3}$

(D) $\frac{-\pi}{3}$

3 When the polynomial $P(x) = x^4 + ax + 2$ is divided by $x^2 + 1$ the remainder is $2x + 3$.

The value of a is

(A) 1

(B) 2

(C) 0

(D) 3

4 Given the points A (7, 14) and B (1, 2), C is a point on AB produced such that $AB : BC = 2:1$.

Find the coordinates of C.

(A) $(-5, -10)$

(B) $(-2, -4)$

(C) $(3,\ 6)$

(D) $(5,\ 10)$

5 Find $\int \frac{1}{\sqrt{1-3x^2}}\,dx$.

(A) $3\sin^{-1}(3x)+C$

(B) $\frac{1}{3}\sin^{-1}(3x)+C$

(C) $\sqrt{3}\sin^{-1}\left(\sqrt{3}\,x\right)+C$

(D) $\frac{1}{\sqrt{3}}\sin^{-1}\left(\sqrt{3}\,x\right)+C$

6 Evaluate $\int_0^{\frac{\pi}{6}} \sin^2\theta\,\mathrm{d}\theta$.

(A) $\frac{\pi}{12}-\frac{\sqrt{3}}{8}$

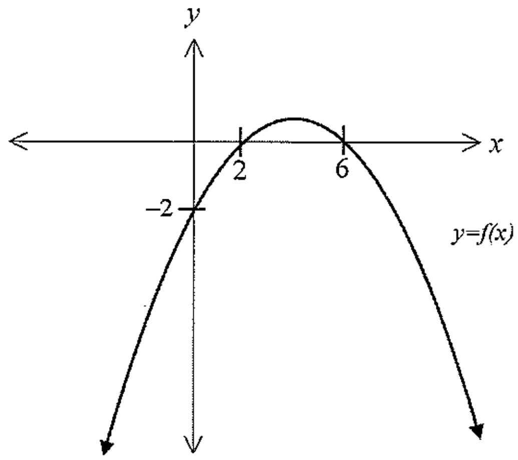
(B) $\frac{\pi}{6}-\frac{\sqrt{3}}{4}$

(C) $\frac{1}{24}$

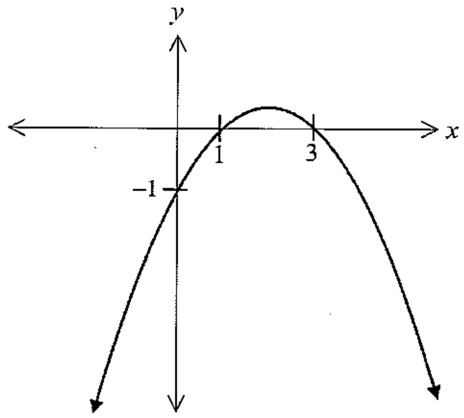
(D) 1

7 The figure on the right shows the graph of $y = f(x)$.

If $2f(x) = g(x)$, which of the following may represent the graph of $y = g(x)$?



(A)



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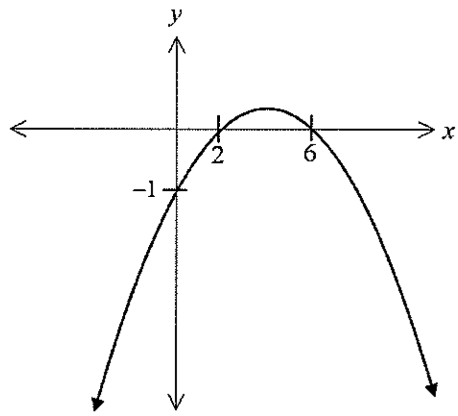
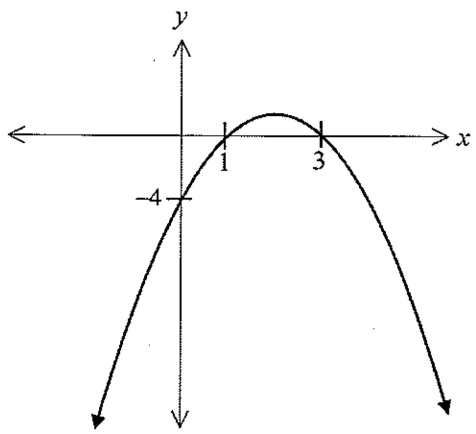
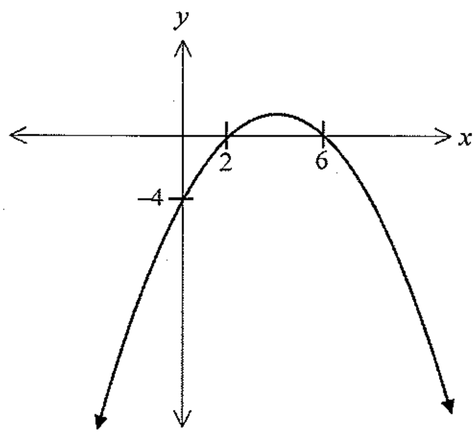


(C)



(D)



8 If $\int_{-a}^{a} f(x)\,dx = 0$, then which one of the following statements is false?

(A) $f(x)$ is an odd function

(B) $\int_{0}^{a} f(x)\,dx = \int_{-a}^{0} f(-x)\,dx$

(C) $\int_{-a}^{a} f(x)\,dx = 2\int_{0}^{a} f(x)\,dx$

(D) The area bounded by the curve $y = f(x)$, the x axis and the lines $x = a$ and $x = -a$ is twice the area bounded by the curve $y = f(x)$, the x axis and the lines $x = 0$ and $x = a$.

9 For $0° \le \theta \le 90°$, the least value of $\dfrac{30}{3\sin^2\theta + 2\sin^2(90° - \theta)}$ is

(A) 5
(B) 6
(C) 10
(D) 15

10 Given n is an integer, the general solution of $\tan\left(2x + \dfrac{\pi}{4}\right) = \sqrt{3}$ is

(A) $x = \dfrac{(12n+1)\pi}{24}$

(B) $x = \dfrac{(3n+1)\pi}{6}$

(C) $x = \dfrac{(12n-1)\pi}{24}$

(D) $x = \dfrac{(6n+1)\pi}{6}$

Section II

60 marks
Attempt Questions 11-14
Allow about 1 hours and 45 minutes for this section.

Answer each question in a SEPARATE writing booklet. Extra booklets are available.

In Questions 11 – 14, your responses should include relevant mathematical reasoning and/or calculations.

Question 11. (15 marks). Use a **Separate** Booklet. **Marks**

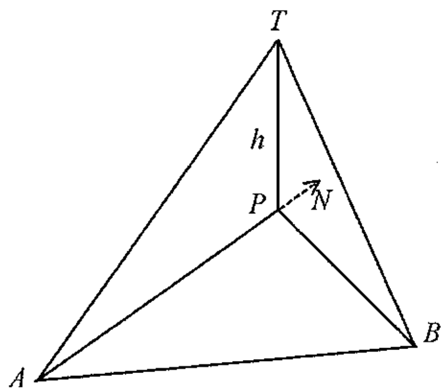
(a) Given $f(x) = x^4 + x^2 - 80$. **2**

Assume there is a zero near $x = 3$. Use Newton's method once to find a better approximation to the root correct to 2 significant figures.

(b) From a point A due south of a tower, TP, the angle of elevation of the top of the tower, T is $25°$ and from a point B due east of the tower is $32°$.

The distance from A to B is 50 metres.

Let the height of tower TP be h metres.



(i) Copy the diagram in your answer booklet and complete with all given information. **1**

(ii) Find an expression for PA in terms of h. **1**

(iii) Find the height of the tower, h, correct to 1 decimal place. **3**

Question 11 continues on page 6.

(c) The function $f(x)$ is defined as $f(x)=\dfrac{3x-4}{x+2}$, where $x \neq -2$.

(i) Find an expression for $f^{-1}(x)$. **2**

(ii) Write down the domain of $f^{-1}(x)$. **1**

(d) Solve $\dfrac{4}{(x-1)^2}>1$. **3**

(e) Find $\displaystyle\int \frac{\ln x}{2x}\,dx$ using the substitution $u=\ln x$. **2**

End of Question 11

Question 12. (15 marks) Use a **Separate** Booklet. **Marks**

(a) Find the term independent of x in the expansion of $\left(2x+\frac{1}{x^2}\right)^6$. **2**

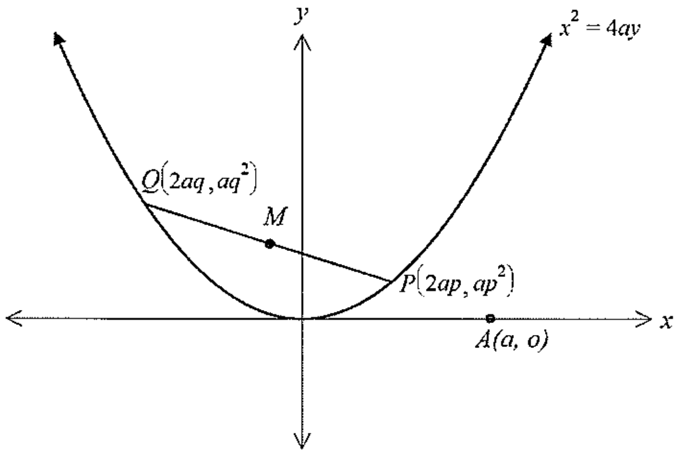
(b) (i) Show that $\tan x = \frac{\sin 2x}{1+\cos 2x}$. **2**

(ii) Hence evaluate $\tan\frac{\pi}{12}$ in simplest form. **2**

(c) Prove by mathematical induction that $8^n - 3^n$ is divisible by 5, where n is a positive integer. **3**

Question 12 continues on page 8.

(d)



In the diagram above, the points $P(2ap, ap^2)$ and $Q(2aq, aq^2)$ lie on the parabola with equation $x^2 = 4ay$.

(i) Write down the coordinates of the midpoint M of the chord PQ. **1**

(ii) Show that the equation of the chord PQ is $y = \frac{(p+q)x}{2} - apq$. **2**

(iii) Show that the condition for the chord PQ produced to pass through the point $A(a,0)$ is $p + q = 2pq$. **1**

(iv) Find the cartesian equation of the locus of M, as the points P and Q move on the parabola subject to the constraint that PQ pass through $A(a,0)$. **2**

End of Question 12

Question 13. (15 marks) Use a **Separate** Booklet. **Marks**

(a) Find the acute angle between the tangents on the curve $y = \tan^{-1} x$ at the points where $x = 0$ and $x = 1$. Answer correct to the nearest degree. **2**

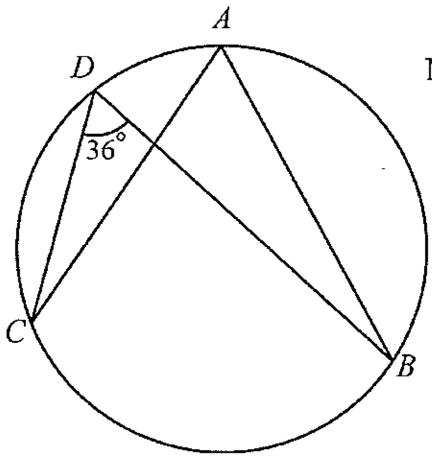
(b) During a chemical reaction, the amount, R kg, of chemical formed at time t hours is modelled by the differential equation

$$\frac{dR}{dt} = 4 - \frac{R}{15}.$$

(i) Show that $R = 60 - 50e^{\frac{-t}{15}}$ is a solution to $\frac{dR}{dt} = 4 - \frac{R}{15}$. **2**

(ii) How long will it take for 20 kg of the chemical to form? Give your answer correct to 2 significant figures. **2**

(c) In the figure below, BD is a diameter of the circle $ABCD$. If $AB=AC$ and $\angle BDC = 36°$, find $\angle ABD$. **3**



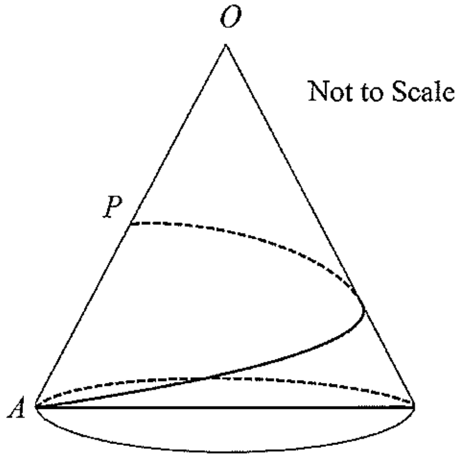
Not to Scale

Question 13 continues on page 10.

(d) A thin sheet of smooth metal is in the shape of a sector of a circle with OA, OB as bounding radii each of length 10 cm, and the angle AOB is $60°$.

(i) Find the length of the arc AB. **1**

(ii) The sheet is now bent to form a right circular cone by welding the radii OA and OB together (and inserting a circular disc to close in the cone at the base).



(α) Find the volume of the cone in terms of π. **3**

(Note: The volume of a right circular cone is, $\frac{1}{3}\pi r^2 h$.)

(β) On the surface of this cone a thin string is pulled tight starting with one end fixed at the point A and passing once round the cone to the other end P which is at the midpoint of OA (as shown in diagram). **2**

Find the exact length of this string.

End of Question 13

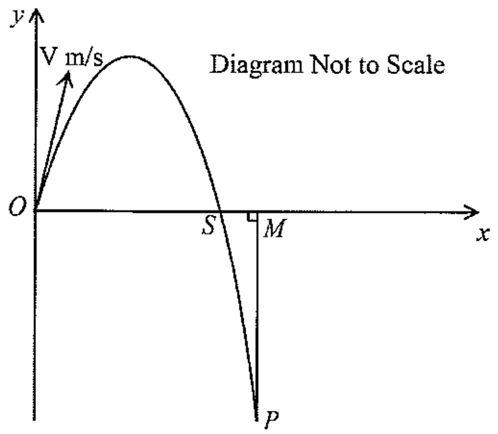
Question 14. (15 marks) Use a **Separate** Booklet. **Marks**

(a) Solve $\sin x - 3\cos x = 3$ for $0° \le x \le 360°$. **3**

(b) A projectile is fired from a point O with initial speed of V m/s at an angle of elevation θ. If x and y are the horizontal and vertical displacements of the projectile in metres from O at time t seconds later then

$x = Vt\ \cos\theta$ and $y = Vt\ \sin\theta - \frac{1}{2}gt^2$ where g m/s^2 is the acceleration due to gravity.

The projectile falls to a point P below the level of O such that $PM = OM$.



(i) Prove that the time taken to reach P is $2V\frac{(\sin\theta + \cos\theta)}{g}$ seconds. **1**

(ii) Show that the distance OM is **2**

$$\frac{V^2}{g}(\sin 2\theta + \cos 2\theta + 1) \text{ metres.}$$

(iii) If $OS = r$, $OM = \frac{4r}{3}$ and $r > 0$, prove that $\sin 2\theta - 3\cos 2\theta = 3$. **3**

(iv) Hence, by using Question 14 part (a), find the value of θ. **2**

(v) Find an expression for the horizontal and vertical components of the velocity. **1**

(vi) If the magnitude of the velocity of the projectile at P is kV m/s, find the exact value of k. **3**

End of Paper

1. B	2. D	3. B	4. B	5. D
6. A	7. D	8. C	9. C	10. A

Q 11

a) $f(x) = x^4 + x^2 - 80$

$f'(x) = 4x^3 + 2x$

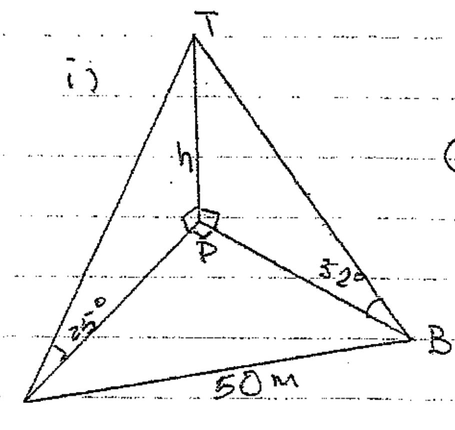
$x_2 = 3 - \frac{f(3)}{f'(3)}$

$= 3 - \frac{3^4 + 3^2 - 80}{4 \times 3^3 + 2 \times 3}$ 1

$= 2.912\ldots$ (2)

$= 2.9$ 1

i)



(1)

b) ii) In $\triangle APT$;

$\tan 25° = \frac{h}{PA}$

$PA = h \cot 25°$ (1)

iii) In $\triangle BPT$;

$\tan 32° = \frac{h}{PB}$

$PB = h \cot 32°$

In $\triangle APB$;

$50^2 = (h \cot 25°)^2 + (h \cot 32°)^2$ 1

$h^2 = \frac{50^2}{\cot^2 25° + \cot^2 32°}$ 1

$= 349.16\ldots$

$h = 18.68\ldots$ (h is a height of tower so $h > 0$) 1

$= 18.7\ m$

(3)

c) $f(x) = \dfrac{3x-4}{x+2}$

i) $x = \dfrac{3y-4}{y+2}$

$xy + 2x = 3y - 4$

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

$3y - xy = 2x + 4$

$y = \dfrac{2x+4}{3-x}$

$f^{-1}(x) = \dfrac{2x+4}{3-x}$ 1 (2)

ii) Domain : all real x ; $x \neq 3$. (1)

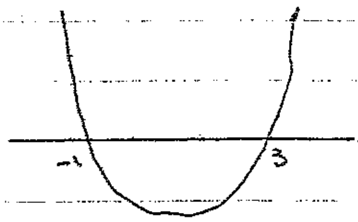
d) $\dfrac{4}{(x-1)^2} > 1$; $x \neq 1$

$4 > x^2 - 2x + 1$

$x^2 - 2x - 3 < 0$

$(x-3)(x+1) < 0$

$-1 < x < 3$



∴ $-1 < x < 3$ except $x = 1$. (3)

e) $\int \dfrac{\ln x}{2x}\, dx$; $u = \ln x$

$du = \frac{1}{x}\, dx$

$= \frac{1}{2}\int \ln x \cdot \frac{1}{x}\, dx$

$= \frac{1}{2}\int u\, du$ 1

$= \frac{1}{2}\left(\frac{1}{2}u^2\right) + C$

$= \frac{1}{4}u^2 + C$

$= \frac{1}{4}(\ln x)^2 + C$ 1 (2)

Q 12

a) $(2x + \frac{1}{x^2})^6$

$= \sum_{r=0}^{6} {}^6C_r (2x)^r (x^{-2})^{6-r}$

Term independent of x

$= {}^6C_4 (2x)^4 (x^{-2})^2$ 1

$= {}^6C_4 \cdot 2^4$

$= 240$ 1 (2)

b) i) RHS $= \frac{\sin 2x}{1+\cos 2x}$

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

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

$= \frac{\sin x}{\cos x}$ 1

$= \tan x$ (2)

$=$ LHS

ii) $\tan \frac{\pi}{12}$

$= \frac{\sin \frac{\pi}{6}}{1+\cos\frac{\pi}{6}}$

$= \frac{\frac{1}{2}}{1+\frac{\sqrt{3}}{2}}$ 1

$= \frac{\frac{1}{2}}{\frac{\sqrt{3}+2}{2}}$

$= \frac{1}{\sqrt{3}+2}$

$= 2 - \sqrt{3}$ 1 (2)

c) Let the statement be $8^n - 3^n = 5P$ where P is an integer.

When $n = 1$;

$8^1 - 3^1 = 8 - 3$

$= 5$ which is divisible by 5.

Assume the statement is true for $n = k$;

i.e. $8^k - 3^k = 5P \Rightarrow 8^k = 5P + 3^k$ —

Prove that the statement is true for $n = k+1$;

i.e. prove that $8^{k+1} - 3^{k+1} = 5Q$ where Q is an integer.

LHS $= 8^{k+1} - 3^{k+1}$

$= 8(8^k) - 3^{k+1}$

$= 8(5P + 3^k) - 3(3^k)$; from *

$= 5 \cdot 8P + 8 \cdot 3^k - 3 \cdot 3^k$

$= 5 \cdot 8P + 5 \cdot 3^k$

$= 5(8P + 3^k)$; since P is an integer, 8P is a[n integer]; since k is a positive integer, 3^k is int[eger]

$= 5Q$; $Q = 8P + 3^k$ is also an integer

Since the statement is true for $n = 1$, assume true for $n = k$ and proved true for $n = k$[+1], so the statement is true for $n = 1 + 1 = 2$, $n = 2 + 1 = 3$, ..., ∴ the statement is true for all positive integers of n.

(3)

1 for intro, * and conclusion

1 for case $n = 1$

1 for correct steps showing $8^{k+1} - 3^{k+1} = 5Q$, Q an integer

d) i) Midpoint M of PQ

$$= \left(\frac{2ap + 2aq}{2} , \frac{ap^2 + aq^2}{2} \right)$$

$$= \left(ap + aq , \frac{ap^2 + aq^2}{2} \right) \quad (1)$$

ii) $$m_{PQ} = \frac{ap^2 - aq^2}{2ap - 2aq}$$

$$= \frac{a(p+q)(p-q)}{2a(p-q)}$$

$$= \frac{1}{2}(p+q) \quad 1$$

Equation of chord PQ is

$$\frac{p+q}{2} = \frac{y - ap^2}{x - 2ap}$$

$$\left(\frac{p+q}{2}\right)x - 2ap\left(\frac{p+q}{2}\right) = y - ap^2$$

$$\frac{(p+q)x}{2} - (ap^2 + apq) + ap^2 = y$$

$$y = \frac{(p+q)x}{2} - ap^2 - apq + ap^2 \quad 1$$

$$y = \frac{(p+q)x}{2} - apq \quad (2)$$

iii) If chord PQ passes through A(a, 0),

then $0 = \frac{1}{2}a(p+q) - apq$ (1)

$$\frac{1}{2}a(p+q) = apq$$

$$\frac{1}{2}(p+q) = pq$$

$$p + q = 2pq$$

iv) $$x_M = ap + aq$$

$$x_M = a(p+q)$$

$$x_M = 2apq \quad \because p+q = 2pq$$

$$y_M = \frac{1}{2}a(p^2 + q^2)$$

$$= \frac{1}{2}a[(p+q)^2 - 2pq]$$

$$= \frac{1}{2}a(p+q)^2 - apq \quad 1$$

$$= \frac{1}{2a}[a^2(p+q)^2] - apq$$

$$= \frac{1}{2a}(x_M)^2 - \frac{1}{2}x_M$$

$$2ay = x^2 - ax$$

$$x^2 - ax - 2ay = 0 \quad 1$$

(2)

Q 13

a) $y = \tan^{-1} x$

$y' = \dfrac{1}{1 + x^2}$

$m_1 = \dfrac{1}{1+0^2} = 1$; m of tangent at $x = 0$ 1

$m_2 = \dfrac{1}{1+1^2} = \dfrac{1}{2}$; m of tangent at $x = 1$

$\tan\theta = \dfrac{1 - \frac{1}{2}}{1 + (1)(\frac{1}{2})}$

$\tan\theta = \dfrac{1}{3}$

The acute angle, $\theta = 18.43\cdots$ 1

$= 18^\circ$ (1)

b) i) $R = 60 - 50e^{\frac{-t}{15}}$

$\Rightarrow 50e^{\frac{-t}{15}} = 60 - R$

$\dfrac{dR}{dt} = 0 - 50\left(\dfrac{-1}{15}e^{\frac{-t}{15}}\right)$ 1

$= \dfrac{1}{15}\left(50e^{\frac{-t}{15}}\right)$

$= \dfrac{1}{15}(60 - R)$ 1

$= 4 - \dfrac{R}{15}$ (2)

ii) $20 = 60 - 50e^{\frac{-t}{15}}$

$-40 = -50e^{\frac{-t}{15}}$

$\dfrac{-t}{15} = \ln\dfrac{4}{5}$ 1

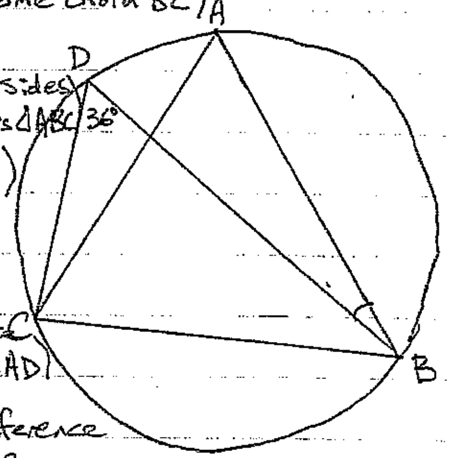
$t = -15\ln\dfrac{4}{5}$

$= 3.347\cdots$ 1

≈ 3.3 hours (2)

c) $\angle BAC = \angle BDC$ (angles at the circumference standing on the same chord BC)

$= 36°$



1 $\angle ACB = \angle ABC$ (angles opposite equal sides AB and AC in isosceles △ABC)

$\angle ACB + \angle ABC + \angle BAC = 180°$ (angles sum of △ABC)

$2\angle ACB + 36° = 180°$

$\angle ACB = 72°$

$\angle DCA = \angle DBA$ (angles at the circumference standing on the same arc AD)

$\angle DCB = 90°$ (angles at the circumference in a semicircle, BD is the diameter)

1 $\angle DCA + \angle ACB = \angle DCB$ (adjacent angles)

$\angle DBA + 72° = 90°$

$\angle DBA = 90° - 72°$

$= 18°$

(3)

d) i) $\angle AOB = 60^\circ$

$= \frac{\pi}{3}$

Length of arc AB

$= 10 \times \frac{\pi}{3}$

$= \frac{10\pi}{3}$ cm ⓵

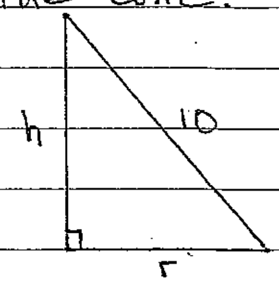
ii) a) Let r be the radius of the cone and h be the height of the cone.

$2\pi r = \frac{10\pi}{3}$

$r = \frac{5}{3}$ cm

$h = \sqrt{10^2 - (\frac{5}{3})^2}$

$= \frac{5\sqrt{35}}{3}$ cm

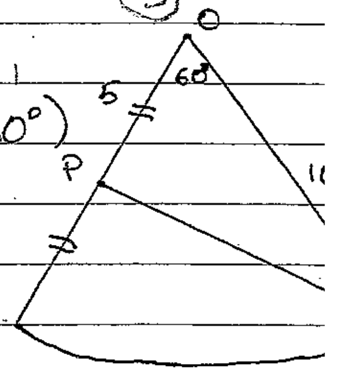


Volume of cone

$= \frac{1}{3} \times \pi \times (\frac{5}{3})^2 \times \frac{5\sqrt{35}}{3}$

$= \frac{125\sqrt{35}\,\pi}{81}$ cm^3

⓷



b) In $\triangle BPO$:

$PB^2 = 5^2 + 10^2 - 2(5)(10)(\cos 60^\circ)$

$= 125 - 100 \times \frac{1}{2}$

$= 75$

$PB = \sqrt{75}$; PB is a length so $PB > 0$, $PB \neq -\sqrt{75}$ A

$= 5\sqrt{3}$

∴ Length of string, $PB = 5\sqrt{3}$ cm.

1 – correct set up
2 – correct set up and acute sol^n
3 – All correct

Q 14

a) $\sin x - 3\cos x = 3$

$\sqrt{10}\sin(x - \theta) = 3$; $\tan\theta = 3 \Rightarrow \theta \approx 71.56$

$\sin(x - \theta) = \frac{3}{\sqrt{10}}$ & $-\theta \le x - \theta \le 360° - \theta$

$x - \theta = 71.56\ldots$ OR $x - \theta = 180° - 71.56\ldots$ 1

$x = 143.13\ldots$ OR $x = 180°$

$\therefore x = 143°$ OR $180°$ (nearest degree)] 1 (3)

b) $\left[\begin{array}{l} x = Vt\cos\theta \\ y = Vt\sin\theta - \frac{1}{2}gt^2 \end{array}\right.$

i) Since PM = OM, at P $x = -y$;

$Vt\cos\theta = \frac{1}{2}gt^2 - Vt\sin\theta$

$\frac{1}{2}gt^2 = Vt(\cos\theta + \sin\theta)$

$t = 0$ OR $\frac{1}{2}gt = V(\sin\theta + \cos\theta)$

However at P, $t \neq 0$; (1)

$\frac{1}{2}gt = V(\sin\theta + \cos\theta)$ r/w

$t = \frac{2V(\sin\theta + \cos\theta)}{g}$

ii) When $t = \frac{2V(\sin\theta + \cos\theta)}{g}$

$x = \frac{V\cos\theta \cdot 2V(\sin\theta + \cos\theta)}{g}$ (1)

$= \frac{V^2}{g}(2\sin\theta\cos\theta + 2\cdot\cos^2\theta)$ (1)

$= \frac{V^2}{g}(\sin 2\theta + \cos 2\theta + 1)$; $\sin 2\theta = 2\sin\theta\cos\theta$ and $\cos 2\theta = 2\cos^2\theta -$

$\Rightarrow 2\cos^2\theta = \cos$ +

(2)

iii) OS = r

$\Rightarrow$ when $y = 0$, $x = r$

$Vt\sin\theta - \frac{1}{2}gt^2 = 0$

$t(V\sin\theta - \frac{1}{2}gt) = 0$

$\frac{1}{2}gt = V\sin\theta$; $t \neq 0$

$t = \frac{2V\sin\theta}{g}$ (1)

When $t = \frac{2V\sin\theta}{g}$,

$x = V\cos\theta \cdot \frac{2V\sin\theta}{g} = r$

$\frac{2V^2\sin\theta\cos\theta}{g} = r$ (1)

$\frac{V^2\sin 2\theta}{g} = r$ — *

$OM = \frac{4r}{3} = \frac{V^2}{g}(\sin 2\theta + \cos 2\theta + 1)$; from (ii

$\frac{4V^2\sin 2\theta}{3g} = \frac{V^2\sin 2\theta}{g} + \frac{V^2}{g}(\cos 2\theta + 1)$; fro

$\frac{V^2\sin 2\theta}{3g} = \frac{V^2}{g}(\cos 2\theta + 1)$ (1) Tying together.

$\frac{\sin 2\theta}{3} = \cos 2\theta + 1$

$\sin 2\theta = 3\cos 2\theta + 3$

$\sin 2\theta - 3\cos 2\theta = 3$ (3)

iv) $2\theta = 143.13\ldots$ OR $180°$

$\theta = 71.56\ldots$ OR $90°$ (1)

However θ is the angle of elevation and the projectile is not fired vertically, $0° < \theta <$

$\therefore \theta = 71.56\ldots$ (1) Explanation and exclusion

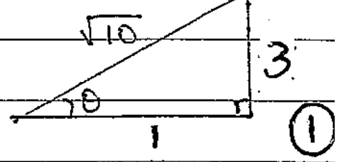
v) $x = Vt\cos\theta \Rightarrow \dot{x} = V\cos\theta$

$y = Vt\sin\theta - \frac{1}{2}gt^2 \Rightarrow \dot{y} = V\sin\theta - gt$] (1

vi) From (a), $\tan\theta = 3$

$\Rightarrow \sin\theta = \frac{3}{\sqrt{10}}$

& $\cos\theta = \frac{1}{\sqrt{10}}$ (1)



$\dot{x} = \frac{V}{\sqrt{10}}$ and $\dot{y} = \frac{3V}{\sqrt{10}} - g\left(\frac{2V}{g}(\sin\theta + \cos\theta\right.$

from

$\dot{y} = \left(\frac{3}{\sqrt{10}} - \frac{6}{\sqrt{10}} - \frac{2}{\sqrt{10}}\right)V$

$= \frac{-5V}{\sqrt{10}}$ (1)

$(\text{Velocity})^2 = \dot{x}^2 + \dot{y}^2 = (kV)^2$

$\left(\frac{V}{\sqrt{10}}\right)^2 + \left(\frac{-5V}{\sqrt{10}}\right)^2 = k^2V^2$ (1)

$\frac{26V^2}{10} = k^2V^2$

$k = \sqrt{\frac{13}{5}}$; since the magnitude of $= kV$, $k > 0$