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Examiners' report

LEVEL 3 CERTIFICATE

FREE STANDING MATHEMATICS QUALIFICATION: ADDITIONAL MATHS

OCR Level 3 Free Standing Mathematics Qualification: Additional Maths

6993

For first teaching in 2018

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Version 1

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Contents

Introduction

Our examiners' reports are produced to offer constructive feedback on candidates' performance in the examinations. They provide useful guidance for future candidates.

The reports will include a general commentary on candidates' performance, identify technical aspects examined in the questions and highlight good performance and where performance could be improved. A selection of candidate responses is also provided. The reports will also explain aspects which caused difficulty and why the difficulties arose, whether through a lack of knowledge, poor examination technique, or any other identifiable and explainable reason.

Where overall performance on a question/question part was considered good, with no particular areas to highlight, these questions have not been included in the report.

A full copy of the question paper and the mark scheme can be downloaded from Teach Cambridge.

Paper 1 series overview

Most candidates had a good grasp of the majority of topics being tested and the mean score was high, as in previous years. The more routine questions were answered well by most candidates and many coped well with those questions designed to be more thought provoking.

Candidates who did well on this paper generally:	Candidates who did less well on this paper generally:
• had a grasp of all the topics being tested • set out their responses well, showing relevant working • responded with clarity and coherence in explanation-type questions.	• lacked confidence in some of the topics being tested • did not plan their response carefully, which impacted its clarity and relevance.

Question 1

1 Find the coefficient of x^3 in the expansion of $(2-3x)^5$. **[3]**

The binomial expansion is a topic of the specification (EN1) but many candidates chose to multiply out 5 brackets. Exemplar 1 shows a successful attempt of this approach, but in most cases it led to numerous arithmetic and algebraic errors. For those using the binomial expansion, most of the errors came from $(-3x)^3$, either forgetting the negative sign or not cubing the 3.

Exemplar 1

1

$(2-3x)^5 \quad \cancel{(2-3x)}\cancel{(2-3x)}\cancel{(2-3x)}(2-3x)(2-3x)$

$(4-12x+9x^2)(2-3x)$

$8-36x+36x^2+18x^2-27x^3$

$(-27x^3+54x^2-36x+8)(9x^2-12x+4)$

$-243x^5-324x^4 \quad -108x^3 \quad -648x^3 \quad -324x^3$

$-1080x^3$

$\therefore -1080$ is the coefficient

This response received 3 out of 3 marks.

Question 2

2 **In this question you must show detailed reasoning.**

Solve the inequality $7 < 3(x-2)+1 < 16$. **[3]**

Most candidates answered this question correctly. Generally, candidates chose to handle each inequality separately before combining them, which proved effective. However, those who attempted a one-step solution sometimes neglected to apply operations to both ends of the inequality.

Question 3

3 Determine the exact value of $x^2 - x + 5$ when $x = 3 + \sqrt{2}$. **[3]**

Because this question demanded detailed reasoning, candidates needed to show their expansion in order to gain full marks. Most managed this well.

The command word 'determine' indicates that justification should be given for any results found, in this question candidates needed to show their expansion in order to gain full marks. Most managed this well.

OCR support

Section 2b in the specification provides guidance to question 'command word' instructions. A useful A4 summary can be downloaded by students from the subject website.

Question 4

4 Determine the equation of the tangent to the curve $y = 4 + x + x^2$ at the point (1, 6). **[4]**

Differentiation caused few problems and most obtained the answer successfully. Those who didn't produce a fully correct response most commonly confused their gradient function, 2*x*+1 with the required equation of the line. Some candidates misunderstood the requirement and found the perpendicular gradient.

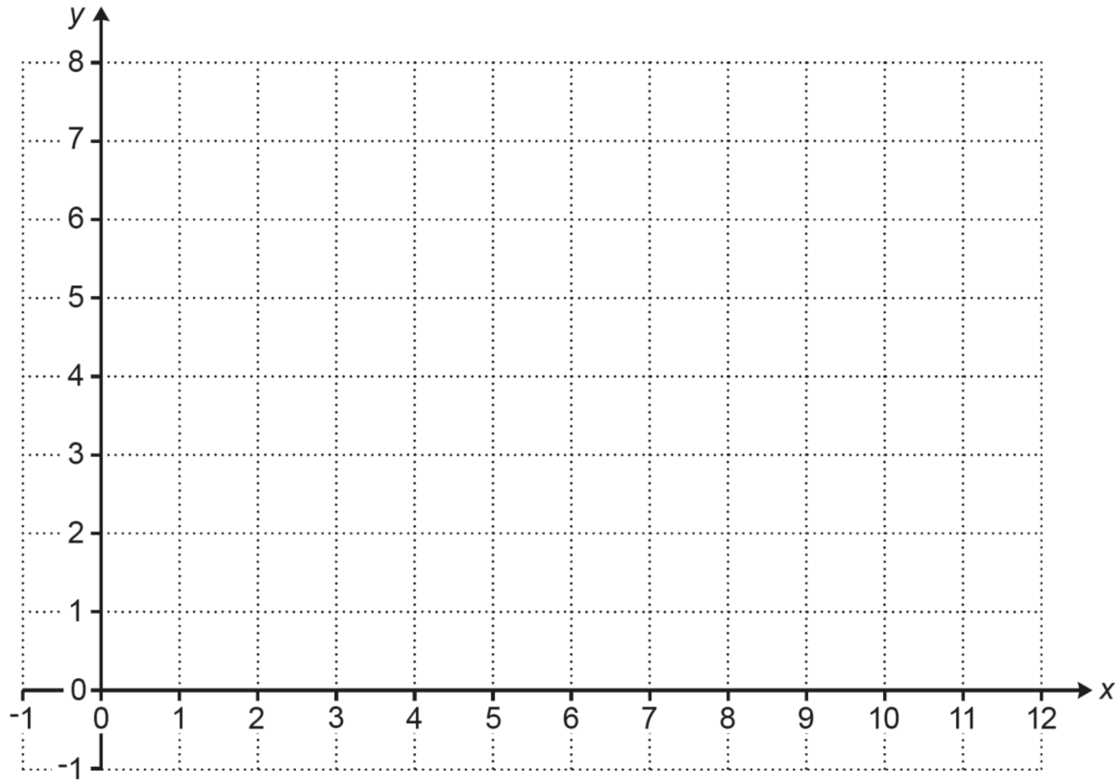
Question 5 (a) and (b)

5 (a) On the grid below, indicate the region for which the following inequalities hold.
You should shade the region that is **not** satisfied by the inequalities.

$2x + 3y \leqslant 12$
$x + 3y \geqslant 9$
$x \geqslant 0$

[4]

5(a)



(b) Write down the minimum value of $2x + y$ within this region. **[1]**

Question 5 (a) and (b) Standards of accuracy were generally good and the vast majority followed the instruction to shade the unwanted region. Those who obtained the correct region also then answered Question 5 (b) correctly.

Question 6 (a)

6 A car accelerates from rest in a straight line. At time t seconds the displacement of the car, s metres, is modelled by the equation

$$s = \frac{t^3}{2} - \frac{t^4}{24}.$$

(a) Determine the maximum velocity of the car. **[6]**

Some students, having correctly obtained v, attempted to find the maximum by substituting integer values only. Although this yielded a correct result, it did not gain full marks since it was not properly established as the maximum. Some tried to substitute expressions for s and v into constant acceleration formulae.

Question 6 (b)

(b) Describe what is happening when $t \geqslant 9$. **[2]**

The question required a response covered when $t = 9$ and when $t > 9$. Many candidates commented on one part but not the other.

Question 7 (a), (b) (i), and (b) (ii)

7 A small club consists of 10 members.

(a) In how many ways can 4 members be chosen from the 10 members? **[2]**

(b) You are given that half of the members are male and half are female.

In how many ways can 4 members be chosen so that

(i) they are either all male or all female, **[2]**

(ii) 2 are male and 2 are female? **[2]**

Many incorrect answers were seen in parts (a) and (b), mostly involving permutations rather than combinations. There was a significant minority of candidates that appeared to misunderstand the request and attempted to find the probability for each outcome.

Permutations and combinations

Candidates frequently misunderstand permutations and combinations. They should ask themselves 'Does order matter?' Choosing two people from a group of 10 to represent the group and choosing a chairman and a secretary from a group of 10 is an easy example to illustrate the difference.

Question 8 (a)

8 In this question you must show detailed reasoning.

(a) Solve the simultaneous equations $y = 2x^2 - 5x + 4$ and $x + y = 2$. **[4]**

Greater success came from the simpler substitution for *y* rather than for *x*, with a slightly greater risk of error in their algebraic manipulation. Many did not spot the simple factorisation and so worked through the quadratic formula

Question 8 (b)

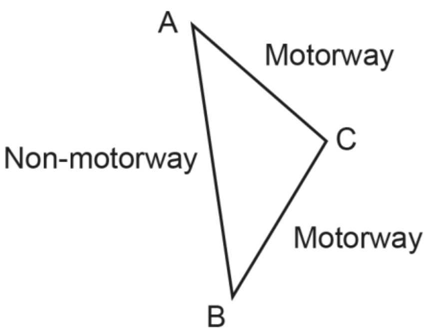
(b) State the geometrical relationship between the graphs of $y = 2x^2 - 5x + 4$ and $x + y = 2$. **[1]**

Just under a half of the cohort recognised that the geometrical significance of the result from 8(a) was that because the two roots to the quadratic equation were coincidental, the line was a tangent to the curve.

Question 9 (a)

9 Tom plans to travel by car from a point A to a point B. There are two routes that he can take. He can take either a motorway route or a non-motorway route.
Tom models the roads used on these two routes as straight lines. The line AB represents the non-motorway route. The lines AC and CB represent the two motorways used for the motorway route.

The diagram illustrates the two routes where C is the junction of the motorways.



Not to scale

You are given that AC = 50 km, CB = 40 km and angle ACB = 120°.

(a) Calculate the distance AB. **[3]**

Finding AB caused few problems. It was encouraging to note that the historically common error $a^2 = b^2 + c^2 - 2bc\cos A \Rightarrow a^2 = \left(b^2 + c^2 - 2bc\right)\cos A$ was rarely seen.

Question 9 (b)

In his model Tom assumes that:

- he drives at a constant speed
- he can move through the junction at C without losing speed
- his speed on the non-motorway route is kv where v is his speed on the motorway route, k is a constant and $k < 1$.

(b) Determine the value of k such that the time taken to travel each route is the same. **[3]**

Many correct answers were obtained but many were not sufficiently justified for a 'determine' question. The first step, to equate times, was required for the method mark. It was possible to obtain the correct answer involving incorrect working so if this step was not seen it was not possible to determine whether the correct method was being used.

Question 10

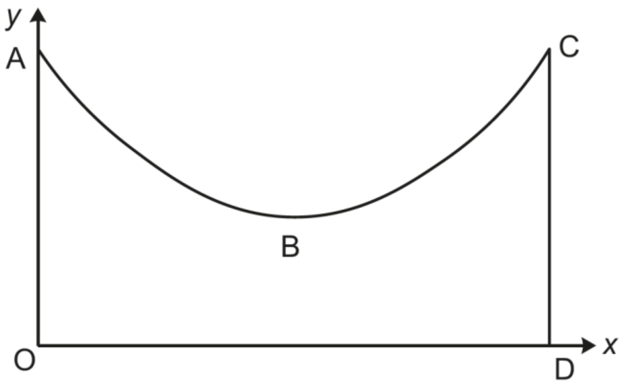
10 In this question you must show detailed reasoning.

Solve the equation $\frac{1}{x-5} - \frac{1}{x} + \frac{5}{6} = 0$. **[5]**

The algebraic manipulation of the fractions was challenging for many candidates. There were many ways to obtain the required quadratic, but errors with expansion of brackets and multiplying negative terms were often seen. A common error was to use a relationship $\frac{a}{b} = 0 \Rightarrow a = b$

Question 11 (a)

11 A rectangular metal plate OACD is aligned on a coordinate system such that O is the origin and A, C and D have coordinates (0, 16), (6, 16) and (6, 0) respectively.
A curved section ABC is removed from OACD to leave the shape OABCD shown in the diagram.
The curved edge ABC has equation $y = x^2 - 6x + 16$ and B is the stationary point on the curve.



(a) By completing the square, determine the coordinates of B. **[3]**

There were few problems with completing the square and stating the resulting minimum point. It is to be noted that the question explicitly requested the completion of the square to be used, so candidates who used calculus did not score.

Question 11 (b)

(b) The line $y = k$ is such that it cuts the **area** of the shape OABCD in half.

Find the value of k. **[5]**

Most carried out the definite integration correctly but there were problems finding the value of k . k = 3 was a common incorrect answer suggesting a vertical rather than horizontal line.

Question 12 (a)

12 Heidi and Charlie have been asked to solve the equation $f(x) = 1.3^x - x = 0$.

(a) Show by sign change that $f(x) = 0$ has a root, α, in the interval [1,2]. **[2]**

There were few problems with the substitution of the two integers but there were many issues with formally and fully stating the conclusion.

Question 12 (b)

(b) Heidi attempts to solve the equation $f(x) = 0$ using the iterative formula $x_{r+1} = \dfrac{\log_{10} x_r}{\log_{10} 1.3}$.

She starts with $x_0 = 1.4$. Show that the sequence derived from this iterative formula fails to find α. **[2]**

The final mark was often lost for either lack of detailed figures or incorrect explanation of the failure. The fact that the iterates went outside the range found in part (a) or (initially) seen to be diverging are not necessarily criteria for failure. Candidates need to go as far as trying to find x_4 to obtain the correct reason.

Question 12 (c)

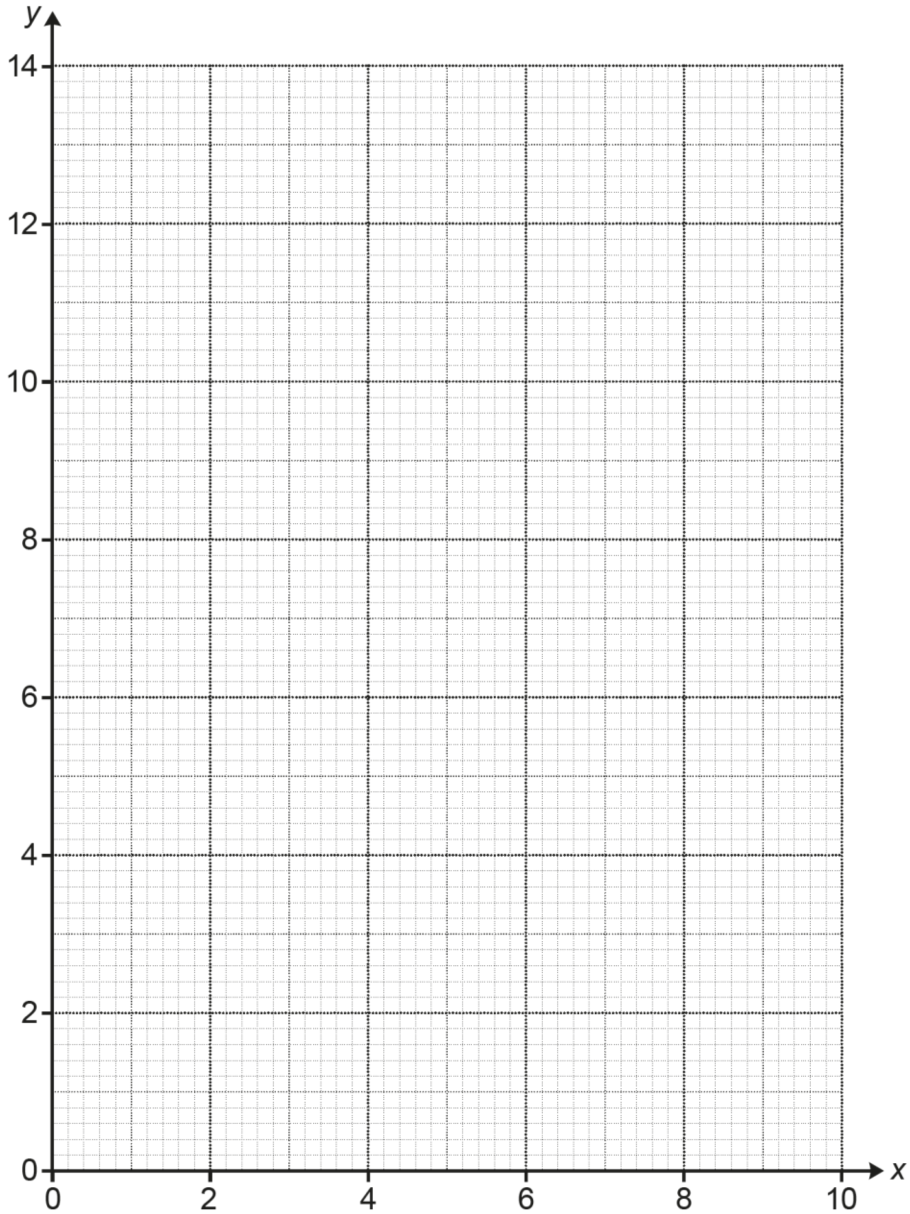
(c) Charlie attempts to solve the equation $f(x) = 0$ using the iterative formula $x_{r+1} = 1.3^{x_r}$.
Starting with $x_0 = 1.4$, determine the value of α correct to **3** significant figures. **[3]**

Candidates generally found no difficulty in finding the required result although some lacked detail.

Question 12 (d) (i)

(d) (i) Plot both the curve $y = 1.3^x$ and the line $y = x$ on the grid below to show that there is another root, β, which you should identify on your graph. **[4]**

12(d)(i)



The graph was generally well done although many did not identify β.

Question 12 (d) (ii)

(ii) Give the integer interval within which β lies. **[1]**

Most candidates gave their range in words, with a few using the more formal interval notation [7,8]. A significant number of candidates gave a single digit or found a decimal approximation for the value of β.

Question 12 (e)

(e) Without doing any further calculation, use your graph to explain why Charlie will not find β using his iterative formula. **[2]**

There were many attempts at this explanation which were creditworthy, but very few identified the gradient as a significant factor.

Question 13 (a)

13 (a) You are given that $\sin 2\theta = 0.7$.

Find the values of θ for $0° \leqslant \theta \leqslant 360°$.
Give your answers correct to **1** decimal place. **[3]**

There was almost uniform success in finding the first root. The most commonly seen error was for candidates to find θ from the incorrect $\sin 2\theta = 0.7 \Rightarrow \sin\theta = 0.35$. It was also not uncommon for candidates to use the correct principal angle of 22.2 to incorrectly calculate 180 – 22.2 for the second root.

Question 13 (b)

(b) Given that $0° < \theta < 90°$, show that $\dfrac{1}{\sin^2\theta} - \dfrac{1}{\tan^2\theta} \equiv 1$. **[3]**

The relevant identities were known and applied correctly but producing a fully correct, clear result was challenging for many candidates. A few tried to connect this part to part(a).

Exemplar 2

13(b)

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

↳ (reciprocal of $\tan^2\theta = \frac{\sin^2\theta}{\cos^2\theta}$)

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

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

because $\sin^2\theta + \cos^2\theta = 1$

$$\frac{1-\cos^2\theta}{1-\cos^2\theta}$$ → terms cancell leaving $\frac{1}{1}$ or 1

This is an example where the minimum number of steps was required. The standard layout for an identity is to start with the left-hand side and manipulate it, using the tan ratio and Pythagoras to obtain the right-hand side but the clear steps here gave an acceptable answer.

Question 14

14 A tower AB stands vertically at a point A. C is a point due south of A and on the same horizontal level. The distance AC is 55 m. From C the angle of elevation of B is 36°.

D is a point due west of the tower and 15 m higher than A and C. The horizontal distance of D from the tower is 35 m.

Find the angle of elevation of B from D. **[5]**

It is advisable to encourage candidates to sketch diagrams to make clear in their own minds what work is required to obtain the correct answer and failure to do so caused a number of candidates to be confused about which triangle they should be working on. The problem involved working with right-angled triangles but many candidates found rather longer ways, many using the sine rule with one of the angles 90^0.

Assessment for learning

Right Angled Triangles

Initial work with triangles in trigonometry involves right-angled triangles and the basic trigonometric ratios of sine, cosine, and tangent. Whilst the sine rule or cosine rule can be used for right angled triangles, the added complexity of the algebraic manipulation means that these are better only applied when finding missing sides or angles in non-right-angled triangles.

Candidates should understand that the sine rule and cosine rule are appropriate when a triangle does not have a right angle, but when it does then the basic ratios should be used.

Solutions to problems often require a combination of Pythagoras' Theorem along with trigonometric rules. The key is to choose the method that fits the triangle; a sketched diagram can help identify where there are right angles to simplify the calculations needed.

Question 15 (a)

15 The table shows population data for a country. t is the number of years after 1920.

Years after 1920 (t)	0	20	40	60	80	100
Population in millions (p)	20	31.7	51.3	79.6	126.2	200

Jane believes that this population growth may be modelled by the equation $p = c \times 10^{kt}$ where c and k are constants.

(a) Derive an equation for $\log_{10} p$ in terms of c, k and t. **[3]**

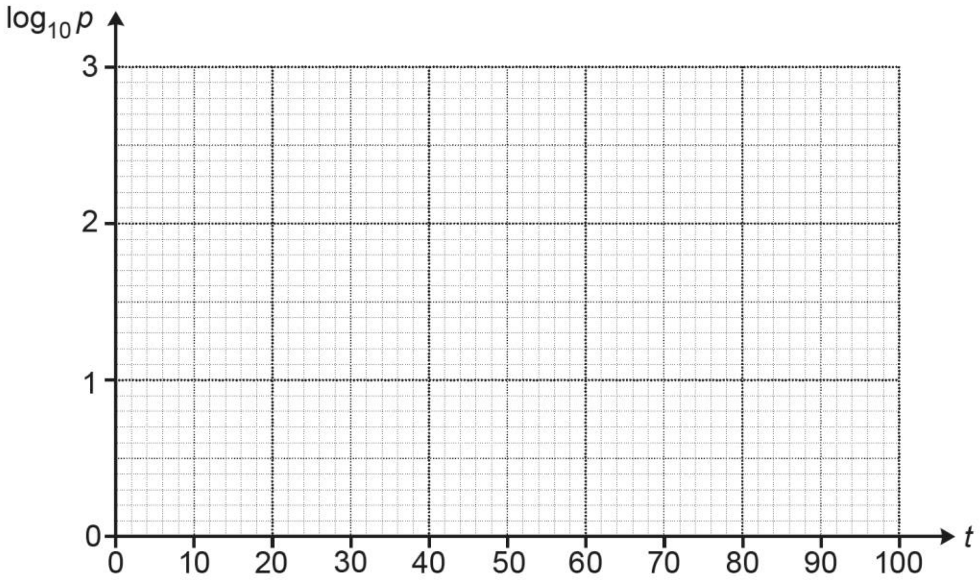
Log laws were known and generally applied well. The fully correct answer required knowledge that $\log_{10} 10 = 1$

Question 15 (b) and (c)

(b) Plot the points $(t, \log_{10}p)$ for the 6 values of t on the grid.
(You may use the blank row in the table above for your values of $\log_{10}p$.) **[3]**

(c) On the grid draw a line of best fit. **[1]**

15(c)



There was generally no difficulty in plotting the correct points and drawing the line of best fit.

Question 15 (d) (i)

(d) (i) State the value of c. **[1]**

Many forgot that the intercept on the y axis was not c but $\log_{10} c$.

Question 15 (d) (ii)

(ii) Using your line, or otherwise, estimate a value for k. **[1]**

It was generally recognised that k represented the gradient of the line. Given that most drew the correct line, most then also obtained the correct answer for this part as well.

Question 15 (e)

(e) According to the model what will be the population in 2040? **[2]**

Candidates using the correct values found little difficulty in obtaining the prediction. Some used the original equation with their values for c and k with t = 120. Others used the form of the equation from part (a). Others extrapolated a value for $\log_{10}$ip from the table of values calculated in part (b). It is worth noting that the variable, p, was given in millions. The question did not ask for the value of p but the population so it was necessary to give the answer in the appropriate units. The answer was therefore 317 million or 317 000 000.

Question 15 (f)

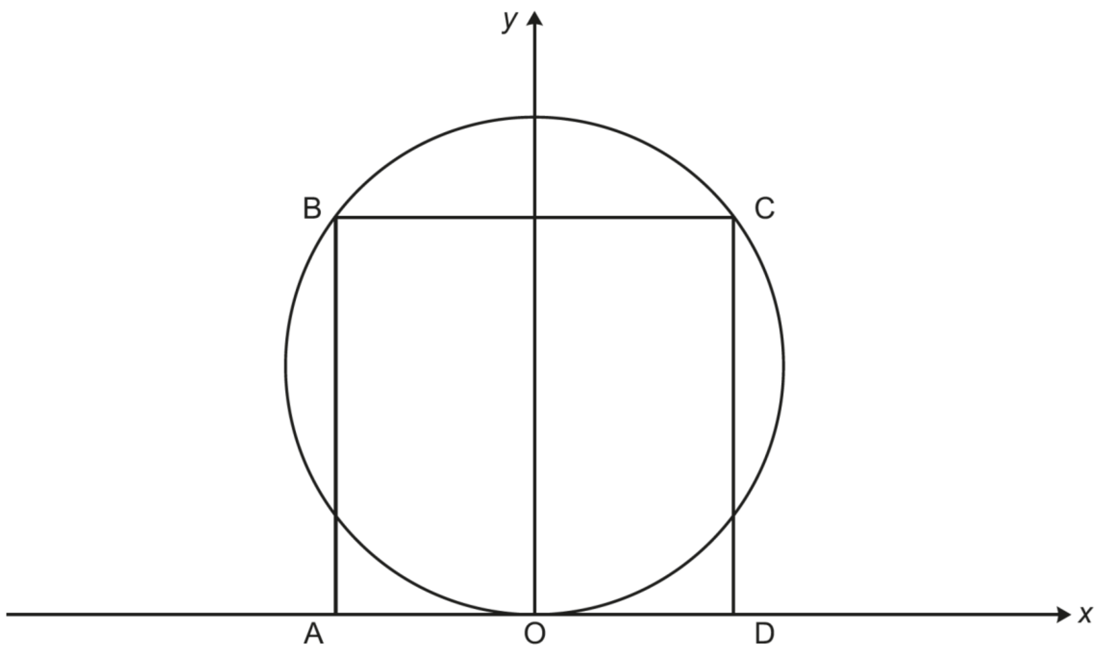
(f) Give a reason why this model may **not** be realistic in the long term. **[1]**

Comments about mathematical models should be given in the context of the problem, rather than generic issues with population models in general.

Question 16 (a)

16 A square with vertices ABCD is aligned in a coordinate system where the coordinates of A, B, C and D are $(-8, 0)$, $(-8, 16)$, $(8, 16)$ and $(8, 0)$ respectively.
The origin, O, is the midpoint of AD.

A circle is such that it passes through the points B and C and touches the line AD at the origin as shown in the diagram.

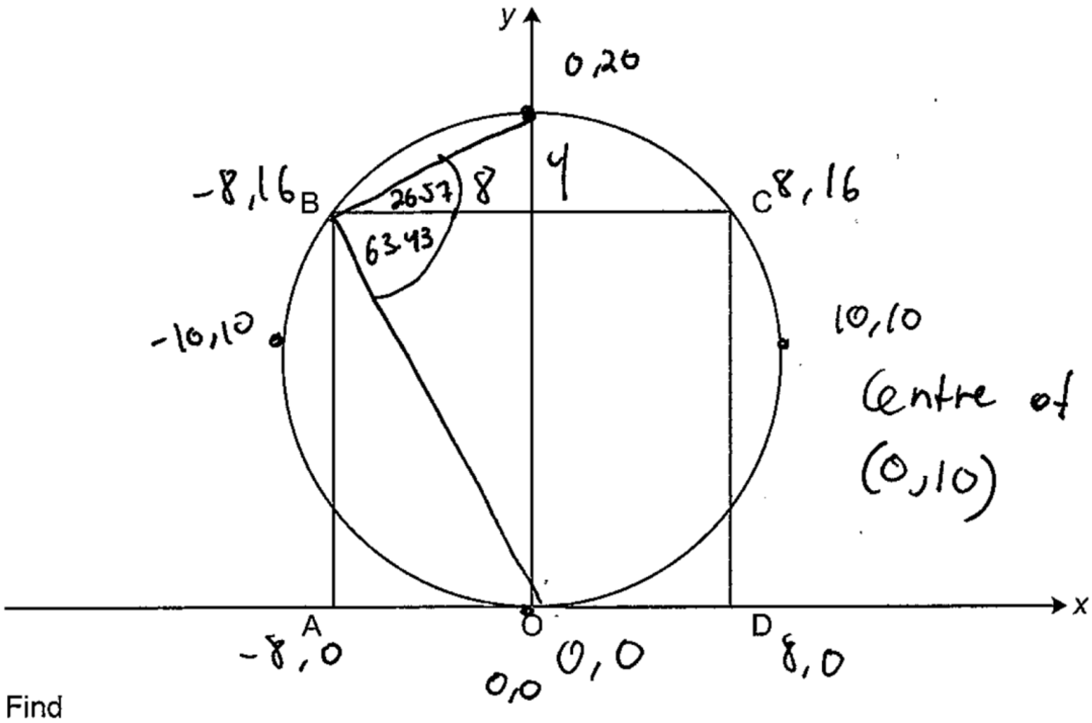


Find

(a) the radius of the circle, **[4]**

This was the most challenging question on the paper. Many candidates struggled to find the radius of the circle (and hence the coordinates of the centre), often believing that the centre of the circle was the centre of the square. There were many ingenious methods, including the double angle formula and the angle in a semicircle. However, where values of angles were found it was impossible to find an exact result.

Exemplar 3



Find

(a) the radius of the circle, **[4]**

(b) the equation of the circle. **[3]**

16(a)	$\angle OBC =$ $BO = \sqrt{8^2 + 16^2} = 8\sqrt{5} = 17.889$
	$AO = \frac{1}{2} BC = 8$
	$\therefore \angle OBC = \cos^{-1}\left(\frac{8}{8\sqrt{5}}\right) = 63.43$
	top vertical segment $= \tan(26.57) \cdot 8 = 4$
	diameter $= 4 + 16 = 20$
	radius $= 20/2 = 10$

In this example the candidate has used the property of a right angle in a semicircle. The angle has been calculated in degrees and the remaining angle found by subtracting from 90. The candidate goes on to use a different ratio to find the required length in the upper triangle. Consequently, the candidate is unable to assert that the length of the side is exactly 4. In such cases the last mark was not awarded. Use of similar triangles will enable the vertical side to be calculated as exactly half of 8 to give the coordinates of the intercept on the *y* axis as exactly (0, 20) and hence the radius as 10.

Question 16 (b)

(b) the equation of the circle. **[3]**

Because of the difficulties of find the radius in part (a) this part was not in general done well although most made good attempts and appeared to know what they had to do.

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