

X100/13/01

NATIONAL
QUALIFICATIONS
2013

WEDNESDAY, 22 MAY
1.00 PM – 4.00 PM

MATHEMATICS
ADVANCED HIGHER

Read carefully

- 1 Calculators may be used in this paper.
- 2 Candidates should answer **all** questions.
- 3 **Full credit will be given only where the solution contains appropriate working.**



Answer all the questions

1. Write down the binomial expansion of $\left(3x - \frac{2}{x^2}\right)^4$ and simplify your answer. 4
2. Differentiate $f(x) = e^{\cos x} \sin^2 x$. 3
3. Matrices A and B are defined by $A = \begin{pmatrix} 4 & p \\ -2 & 1 \end{pmatrix}$ and $B = \begin{pmatrix} x & -6 \\ 1 & 3 \end{pmatrix}$.
- (a) Find A^2 . 1
- (b) Find the value of p for which A^2 is singular. 2
- (c) Find the values of p and x if $B = 3A'$. 2
4. The velocity, v , of a particle P at time t is given by
- $$v = e^{3t} + 2e^t.$$
- (a) Find the acceleration of P at time t . 2
- (b) Find the distance covered by P between $t = 0$ and $t = \ln 3$. 3
5. Use the Euclidean algorithm to obtain the greatest common divisor of 1204 and 833, expressing it in the form $1204a + 833b$, where a and b are integers. 4
6. Integrate $\frac{\sec^2 3x}{1 + \tan 3x}$ with respect to x . 4
7. Given that $z = 1 - \sqrt{3}i$, write down \bar{z} and express \bar{z}^2 in polar form. 4
8. Use integration by parts to obtain $\int x^2 \cos 3x \, dx$. 5
9. Prove by induction that, for all positive integers n ,
- $$\sum_{r=1}^n (4r^3 + 3r^2 + r) = n(n+1)^3. \quad 6$$

10. Describe the loci in the complex plane given by:

(a) $|z + i| = 1$;

2

(b) $|z - 1| = |z + 5|$.

3

11. A curve has equation

$$x^2 + 4xy + y^2 + 11 = 0.$$

Find the values of $\frac{dy}{dx}$ and $\frac{d^2y}{dx^2}$ at the point $(-2, 3)$.

6

12. Let n be a natural number.

For each of the following statements, decide whether it is true or false.

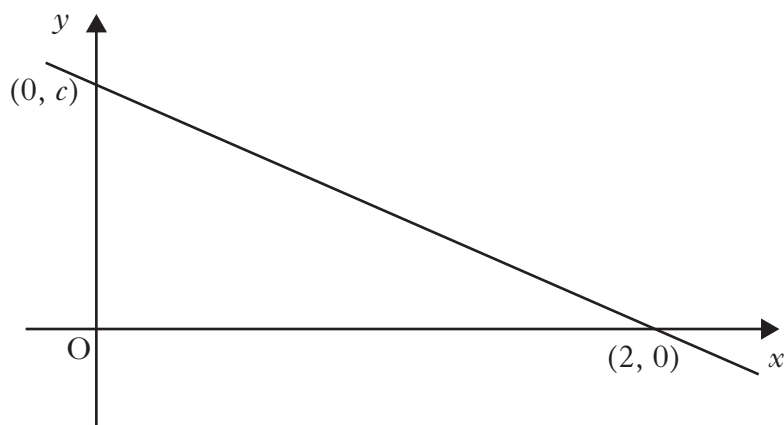
If true, give a proof; if false, give a counterexample.

A If n is a multiple of 9 then so is n^2 .

B If n^2 is a multiple of 9 then so is n .

4

13. Part of the straight line graph of a function $f(x)$ is shown.



(a) Sketch the graph of $f^{-1}(x)$, showing points of intersection with the axes.

2

(b) State the value of k for which $f(x) + k$ is an odd function.

1

(c) Find the value of h for which $|f(x + h)|$ is an even function.

2

[Turn over for Questions 14 to 17 on Page four

14. Solve the differential equation

$$\frac{d^2y}{dx^2} - 6\frac{dy}{dx} + 9y = 4e^{3x}, \text{ given that } y = 1 \text{ and } \frac{dy}{dx} = -1 \text{ when } x = 0. \quad 11$$

15. (a) Find an equation of the plane π_1 , through the points $A(0, -1, 3)$, $B(1, 0, 3)$ and $C(0, 0, 5)$. 4

(b) π_2 is the plane through A with normal in the direction $-\mathbf{j} + \mathbf{k}$.
Find an equation of the plane π_2 . 2

(c) Determine the acute angle between planes π_1 and π_2 . 3

16. In an environment without enough resources to support a population greater than 1000, the population $P(t)$ at time t is governed by Verhurst's law

$$\frac{dP}{dt} = P(1000 - P).$$

Show that

$$\ln \frac{P}{1000 - P} = 1000t + C \quad \text{for some constant } C. \quad 4$$

Hence show that

$$P(t) = \frac{1000K}{K + e^{-1000t}} \quad \text{for some constant } K. \quad 3$$

Given that $P(0) = 200$, determine at what time t , $P(t) = 900$. 3

17. Write down the sums to infinity of the geometric series

$$1 + x + x^2 + x^3 + \dots$$

and

$$1 - x + x^2 - x^3 + \dots$$

valid for $|x| < 1$.

Assuming that it is permitted to integrate an infinite series term by term, show that, for $|x| < 1$,

$$\ln \left(\frac{1+x}{1-x} \right) = 2 \left(x + \frac{x^3}{3} + \frac{x^5}{5} + \dots \right). \quad 7$$

Show how this series can be used to evaluate $\ln 2$.

Hence determine the value of $\ln 2$ correct to 3 decimal places. 3

[END OF QUESTION PAPER]