

Answer all questions in the answer booklet provided. Please start each question on a new page. Full marks are not necessary to be awarded for a correct answer with no working. Answers must be supported by working and/or explanations. Solutions found from a graphic display calculator should be supported by suitable working. For example, if graphs are used to find a solution, you should sketch them as part of your answer. Where an answer is incorrect, some marks may be given for a correct method, provided this is shown by written working. You are therefore advised to show all working.

1. [Maximum mark: 25]

This question will investigate the patterns in a sequence of sine functions using the identities in trigonometry and determine the sum of trigonometric ratios with large angles.

Consider the sequence of sine functions $\{f_n\}$ where $f_n(x) = \sin(2^{n-1} \cdot x)$ for $n \in \mathbb{N}^*$ and $x \in \mathbb{R}$.

(a) Find an expression of $f_2(x)$ in terms of $f_1(x)$ and $f_3(x)$. [4]

(b) Find an expression of $f_4(x)$ in terms of $f_2(x)$ and $f_6(x)$. [2]

(c) Hence show that $f_n(x) = 2\left(1 - 2(f_{n-1}(x))^2\right)f_{n-1}(x)$. [3]

(d) Prove by induction that $\cos\left(\frac{2^n\pi}{3}\right) = -\frac{1}{2}$ for all $n \in \mathbb{N}^*$. [4]

(e) Hence show that the sequence $f_1\left(\frac{2\pi}{3}\right), f_2\left(\frac{2\pi}{3}\right), f_3\left(\frac{2\pi}{3}\right), \dots$ is geometric by identifying the first term and the common ratio. [4]

(f) Determine if the geometric series $S = \sum_{n=1}^{\infty} f_n\left(\frac{2\pi}{3}\right)$ is convergent. [2]

(g) Hence or otherwise, find the exact value of the sum. [4]

$$\sin\left(\frac{\pi}{3}\right) = \sin\left(\frac{2\pi}{3}\right) + \sin\left(\frac{4\pi}{3}\right) + \sin\left(\frac{8\pi}{3}\right) + \dots + \sin\left(\frac{4096\pi}{3}\right).$$

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