Mathematical Methods Calculus Investigation

Stationary points in a function are those where the function's instantaneous rate of change is zero. If a tangent were drawn across that point, the line would be completely horizontal and have no gradient. The function changes direction at turning points, which are stationary positions. All stationary points are turning points, but not all turning points are stationary points.

Points of inflection are points on a graph where the shape shifts from concave to convex or vice versa. There can be a maximum of two turning points and a minimum of zero in a cubic function. Every cubic function, however, must have at least one point of inflection. The goal of this study is to discover the relationship between stationary points and inflection points in a cubic function. The first portion of the enquiry will focus on locating the stationary points and points of inflection in a group of cubic functions and determining a common link between them. The second section investigates cubic functions under various settings in order to test the validity of the discovered relationship regardless of the conditions. The final section looks at how to change the number of stationary points in a cubic function and whether the established relationship still holds for all cubic functions. Finally, the fourth section examines the impact of the first coefficient on the relationship between stationary and inflection points.

The first stage of the enquiry aimed to establish a link between stationary locations and inflection points. This section will look at three cubic functions. To begin, the function's turning points were determined by determining the function's derivative using the differentiation process, which is done either using first principles or by multiplying the power with the number multiplying the variable, subtracting the power by 1, and removing the constant value from the function, represented by the equation $x^n = nx^{n-1}$. The latter procedure was utilised, and the outcome was a quadratic function.

Cubic function a: $y = x^3 - 3x^2 - 9x + 7$

Derivative a: $\frac{dy}{dx} = 3x^2 - 6x - 9$

To find the x intercepts, these were factorised even more. The x values of the intercepts would thus be the same as the x values of the cubic function's stationary points.

Derivative a: $\frac{dy}{dx} = 3(x^2 - 2x - 3)$

$\rightarrow \frac{dy}{dx} = 3(x + 1)(x - 3)$

X intercepts: (-1, 0) and (3, 0)

The x value found was simply replaced into the variables of the cubic function to determine the exact coordinate point for the stationary point.

$y = (-1)^3 - 3(-1)^2 - 9(-1) + 7$

First stationary point: (-1, 12)

$y = 3^3 - 3(3)^2 - 9(3) + 7$

Second stationary point: (3, -20)

In most cases, stationary points are either maximum or minimum turning points, and a sign diagram for the derivative function was used to identify this. Negative areas correspond to areas where the y value is dropping, and vice versa. It is a maximum turning point if the intercept point is between the positive and negative areas, and it is a minimum turning point if the intercept point is between the negative and positive areas.

Maximum turning point: (-1, 12)   Minimum turning point: (3, -20)

Cubic functions generally have sections where the shape of the line drawn is either concave or convex, the point where the change in shape occurs is referred to as the point of inflection. The point was found through the same process used to determine the stationary points, but the derivative function was differentiated instead of the cubic function.

Derivative a: $\frac{dy}{dx} = 3x^2 - 6x - 9$

Second derivative a: $\frac{d^2y}{dx^2} = 6x - 6$

Factorise: $0 = 6(x - 1)$

X intercept: (1, 0)

Substitute: $y = 1^3 - 3(1)^2 - 9(1) + 7$

Point of inflection a: (1, -4)

In order to find which part of a function is concave or convex, another sign diagram can be constructed for the Second derivative function, the negative parts are concave, and the positive parts are convex.

Concave: $x \leq 1$ Convex: $x \geq 1$

The same process was done for function b and c, refer to appendix for calculations. The results are put into a table shown below.

Mathematical Methods

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