

DP IB Maths: AA HL



Your notes

5.5 Optimisation

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5.5.1 Modelling with Differentiation

Modelling with Differentiation

What can be modelled with differentiation?

- Recall that **differentiation** is about the **rate of change** of a function and provides a way of finding **minimum** and **maximum** values of a function
- Anything that involves **maximising** or **minimising** a quantity can be modelled using differentiation; for example
 - minimising the cost of raw materials in manufacturing a product
 - the maximum height a football could reach when kicked
- These are called **optimisation** problems

What modelling assumptions are used in optimisation problems?

- The quantity being optimised needs to be dependent on a **single** variable
 - If other variables are initially involved, **constraints** or **assumptions** about them will need to be made; for example
 - minimising the cost of the **main** raw material – timber in manufacturing furniture say
 - the cost of screws, glue, varnish, etc can be fixed or considered **negligible**
- Other **modelling assumptions** may have to be made too; for example
 - ignoring air resistance and wind when modelling the path of a kicked football

How do I solve optimisation problems?

- In **optimisation** problems, letters other than **x**, **y** and **f** are often used including capital letters
 - **V** is often used for volume, **S** for surface area
 - **r** for radius if a circle, cylinder or sphere is involved
- **Derivatives** can still be found but be clear about which letter is representing the independent (**x**) variable and which letter is representing the dependent (**y**) variable
 - A GDC may always use **x** and **y** but ensure you use the correct letters throughout your working and final answer
- Problems often start by **linking** two connected quantities together – for example **volume** and **surface area**
 - Where more than one variable is involved, **constraints** will be given such that the quantity of interest can be rewritten in terms of **one** variable
- Once the quantity of interest is written as a function of a single variable, **differentiation** can be used to **maximise** or **minimise** the quantity as required

STEP 1

Rewrite the quantity to be optimised in terms of a single variable, using any constraints given in the question

STEP 2

Differentiate and solve the derivative equal to zero to find the "x"-coordinate(s) of any stationary points

STEP 3

If there is more than one stationary point, or the requirement to justify the nature of the stationary point, differentiate again

STEP 4

Use the second derivative to determine the nature of each stationary point and select the maximum or minimum point as necessary

STEP 5

Interpret the answer in the context of the question

 **Examiner Tip**

- The first part of rewriting a quantity as a single variable is often a "show that" question – this means you may still be able to access later parts of the question even if you can't do this bit
- Even when an algebraic solution is required you can still use your GDC to check answers and help you get an idea of what you are aiming for



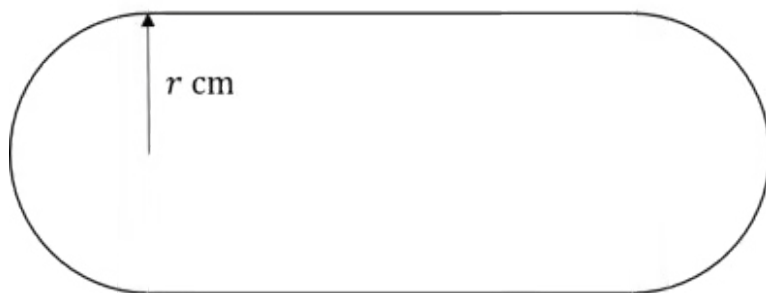
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Worked example

A large allotment bed is being designed as a rectangle with a semicircle on each end, as shown in the diagram below.



The total area of the bed is to be $100\pi \text{ m}^2$.

- a) Show that the perimeter of the bed is given by the formula

$$P = \pi \left(r + \frac{100}{r} \right)$$



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STEP 1: Rewrite P as powers of r

$$P = \pi(r + 100r^{-1})$$

STEP 2: $\frac{dP}{dr} = \pi(1 - 100r^{-2})$

$$\therefore \frac{dP}{dr} = \pi \left(1 - \frac{100}{r^2} \right)$$

c) Find the value of r that minimises the perimeter.

STEP 2: $\pi \left(1 - \frac{100}{r^2} \right) = 0$

$$r^2 - 100 = 0$$

$$r = 10 \quad (\text{reject } -10 \text{ as } r \text{ is a length})$$

This is the only stationary point so we can assume it is minimal.

$$\therefore r = 10 \text{ m minimises the perimeter}$$

d) Hence find the minimum perimeter.



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STEP 5: Interpret answer in context

$$\begin{aligned} \text{Minimum perimeter is when } r=10 \\ \therefore P = \pi \left(10 + \frac{100}{10} \right) = 20\pi \end{aligned}$$

Minimum perimeter is 20π m

Use your GDC to check

e) Justify that this is the minimum perimeter.

STEP 4: Use second derivative

$$\frac{d^2P}{dr^2} = \pi (200r^{-3})$$

$$\text{at } r=10, \frac{d^2P}{dr^2} = \frac{\pi}{5} > 0 \therefore \text{minimum}$$

$\therefore 20\pi$ is the minimum perimeter