Cambridge IGCSE · Mathematics 0580 · Notes

Differentiation

Read online at **pastopic.com/cambridge/mathematics-0580/notes/differentiation**

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Read first: **Equations and changing the subject**, **Graphs of functions and sketching curves**

What you need to know

Extended only: this whole topic is Extended content (syllabus E2.12). Core candidates do not study differentiation.

By the end of this topic you should be able to:

1. **Estimate the gradient of a curve** at a point by drawing a tangent there and working out the tangent's gradient.
2. **Differentiate** terms of the form ax^n, where a is a number (it can be a fraction) and n is a positive whole number or 0, and sums of up to three such terms, such as $2x^3 - 5x^2 + 4$. Write the answer with $\frac{dy}{dx}$ notation.
3. **Use the derivative** to find the gradient of a curve at a point and to find its **turning points** (also called stationary points).
4. **Decide whether a turning point is a maximum or a minimum**, by any sound method: an accurate sketch, the second derivative $\frac{d^2y}{dx^2}$, or the sign of the gradient either side of the point.

Points of inflection are **not** in the syllabus, and you only differentiate whole-number powers of x: nothing like $\frac{1}{x}$ or $\sqrt{x}$.

Understand it

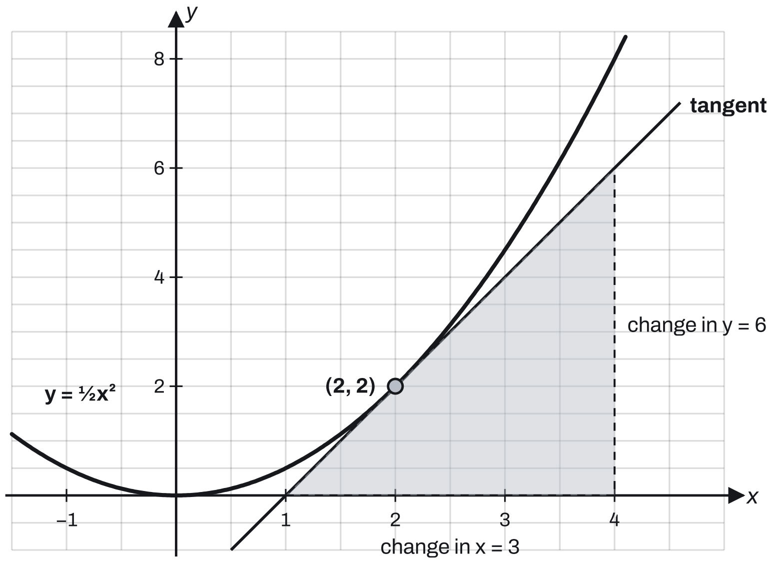
The gradient of a curve

A straight line has the same gradient everywhere. A curve does not: it is steep in some places and flat in others. The **gradient of a curve at a point** is the gradient of the **tangent** at that point, the straight line that just touches the curve there without cutting across it.

You can **estimate** it from a drawn graph:

1. Place a ruler so it touches the curve at the point, with equal gaps on either side, and draw the tangent. Make it long.

2. Pick two points on the tangent that are far apart and easy to read.
3. Gradient $= \dfrac{\text{change in } y}{\text{change in } x}$. It is negative if the tangent slopes down from left to right.



gradient = 6 ÷ 3 = 2

For $y = \frac{1}{2}x^2$ the tangent at $(2, 2)$ passes through $(1, 0)$ and $(4, 6)$, so its gradient is $\frac{6-0}{4-1} = \frac{6}{3} = 2$. A tangent drawn by hand is never perfect, so this is only an estimate. Differentiation gives the exact value.

The derivative

Differentiating turns the equation of a curve into a formula for its gradient, called the **derivative** or **gradient function**, written $\dfrac{dy}{dx}$ (say "d y by d x"). The rule for each term is: **multiply by the power, then take one off the power**.

$$y = ax^n \quad \Rightarrow \quad \frac{dy}{dx} = anx^{n-1}$$

- $x^3 \to 3x^2$, and $4x^3 \to 12x^2$ (the 4 stays as a multiplier).
- $-5x^2 \to -10x$. Multiply the coefficient by the power: $-5 \times 2 = -10$.
- $7x = 7x^1 \to 7x^0 = 7$. An x term becomes a **number**; x on its own becomes 1.
- $4 = 4x^0 \to 0$. A number on its own has gradient 0, so it **disappears**.
- $\frac{1}{2}x^2 \to x$.

Differentiate a sum one term at a time: $y = 2x^3 - 5x^2 + 4$ gives $\dfrac{dy}{dx} = 6x^2 - 10x$.

If the curve is given with brackets, such as $y = x(x+1)(x-3)$, **expand first** ($y = x^3 - 2x^2 - 3x$), then differentiate each term.

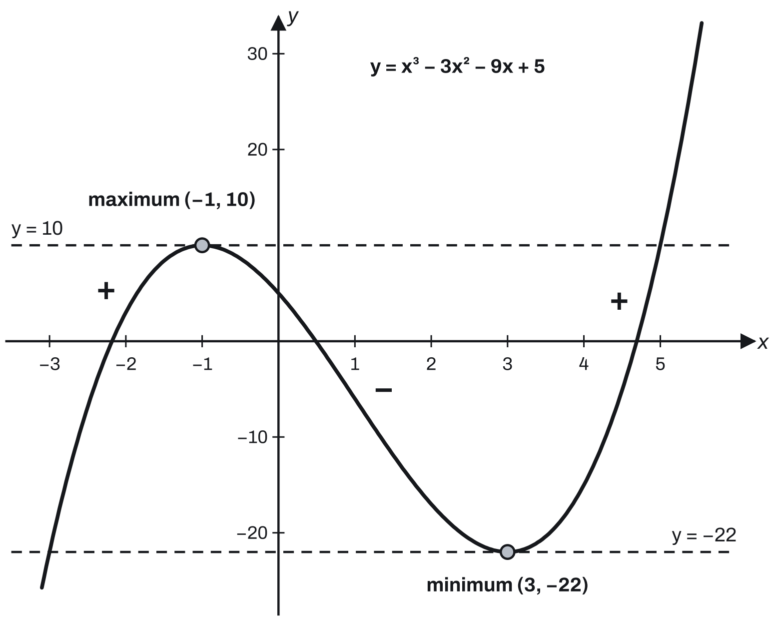
Gradient at a point

$\dfrac{dy}{dx}$ is a formula for the gradient everywhere. To get the gradient at one point, **substitute that point's x-value into $\dfrac{dy}{dx}$**, not into y. For $y = \frac{1}{2}x^2$, $\frac{dy}{dx} = x$, so at $x = 2$ the gradient is exactly 2, agreeing with the tangent in the diagram.

A tangent is a straight line, so once you know its gradient m and one point on it, you can write its equation $y = mx + c$ exactly as in coordinate geometry.

Turning points

At the top of a hump or the bottom of a dip, the tangent is flat, so **the gradient is 0**. These are the **turning points** (or **stationary points**). To find them, solve $\dfrac{dy}{dx} = 0$ to get the x-values, then substitute each x into the **curve's equation** to get y.



For $y = x^3 - 3x^2 - 9x + 5$: $\frac{dy}{dx} = 3x^2 - 6x - 9 = 3(x+1)(x-3)$, which is 0 when $x = -1$ or $x = 3$. Substituting into y gives the turning points $(-1, 10)$ and $(3, -22)$.

A quadratic has one turning point, a cubic $ax^3 + bx^2 + cx + d$ has two or none, and a quartic (x^4 term) can have three.

Maximum or minimum?

A **maximum** is the top of a hump; a **minimum** is the bottom of a dip. There are three accepted ways to decide which one you have.

1. **The second derivative.** Differentiate $\dfrac{dy}{dx}$ again to get $\dfrac{d^2y}{dx^2}$ (the rate at which the gradient changes). Substitute the turning point's x-value:

- $\frac{d^2y}{dx^2} < 0$ (negative): the gradient is falling, so the curve is a hump: **maximum**;
- $\frac{d^2y}{dx^2} > 0$ (positive): the gradient is rising, so the curve is a dip: **minimum**.

Above, $\frac{d^2y}{dx^2} = 6x - 6$: at $x = -1$ it is -12, so $(-1, 10)$ is a maximum; at $x = 3$ it is 12, so $(3, -22)$ is a minimum.

2. **The gradient either side.** Work out $\frac{dy}{dx}$ just to the left and just to the right (without passing another turning point). At a maximum the signs go $+,\ 0,\ -$ (up, flat, down); at a minimum they go $-,\ 0,\ +$. Above, at $x = -2$ the gradient is 15 and at $x = 0$ it is -9: $+, 0, -$, a maximum.

3. **A sketch.** A cubic with a **positive** x^3 term rises from bottom left to top right, so its left turning point is the maximum and its right one the minimum. A **negative** x^3 term flips this. A quadratic with a positive x^2 term has a minimum; with a negative x^2 term, a maximum. The sketch must match the coordinates you found.

Turning points and the number of solutions

The solutions of $f(x) = k$ are where the horizontal line $y = k$ meets the curve $y = f(x)$. For the cubic above, a line **between** the two turning points ($-22 < k < 10$) crosses the curve **three** times. A line **through** a turning point ($k = 10$ or $k = -22$) touches it there and crosses once more: **two** solutions. A line above the maximum or below the minimum crosses only **once**.

Key facts and formulas

"Given" means it is on the List of formulas printed on page 2 of Papers 2 and 4. "Learn it" means you must remember it: there are no differentiation formulas on the list.

Formula	Status
$\frac{d}{dx}(ax^n) = anx^{n-1}$	Learn it
$\frac{d}{dx}(ax) = a$, and $\frac{d}{dx}(\text{number}) = 0$	Learn it
Differentiate a sum term by term	Learn it
Gradient at a point: substitute its x-value into $\frac{dy}{dx}$	Learn it
Turning (stationary) point: $\frac{dy}{dx} = 0$	Learn it
$\frac{d^2y}{dx^2} < 0$: maximum; $\frac{d^2y}{dx^2} > 0$: minimum	Learn it
Maximum: gradient $+,\ 0,\ -$; minimum: gradient $-,\ 0,\ +$	Learn it
Gradient from two points on a tangent: $m = \frac{y_2 - y_1}{x_2 - x_1}$	Learn it
Line: $y = mx + c$; perpendicular gradients multiply to -1	Learn it

Formula	Status
$ax^2 + bx + c = 0 \Rightarrow x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$	Given

How to do it

We have tagged 30 questions on this topic in Papers 2 and 4, 2021–2025. 19 of them mix two or more types, so the counts add up to more than 30.

Question type	Questions
Find the turning points	20
Find the derivative	10
Gradient at a given point	7
Maximum or minimum?	5
Equation of a tangent	5
Use the turning points: sketch, or count solutions of $f(x) = k$	5
Find unknown constants from the derivative	4
Points where the gradient has a given value	2

1. Find the turning points (20 questions)

1. **Differentiate** and write $\dfrac{dy}{dx} = \ldots$
2. **Set** $\dfrac{dy}{dx} = 0$ and write that equation down.
3. **Solve it.** Usually a quadratic:
   - with no number term, such as $3x^2 - 12x = 0$: take out the common factor, $3x(x-4) = 0$, so $x = 0$ or $x = 4$. **Never divide by** x, or you lose $x = 0$;
   - otherwise factorise, or use the quadratic formula (it is on the formula list), especially when the answers must be given to 1 or 2 decimal places;
   - a quartic such as $4x^3 - 36x = 0$ gives $4x(x^2 - 9) = 0$, so $x = 0, 3, -3$: three turning points.
4. **Find each** y by substituting each x into the **curve's equation**, not into $\dfrac{dy}{dx}$ or $\dfrac{d^2y}{dx^2}$.
5. Give each point as coordinates (x, y).

Variations you will meet:

- **"You must show all your working."** A table of values or a calculator's graph earns nothing here: the marks are for differentiating and solving $\dfrac{dy}{dx} = 0$.

- **Only the x-values**, for example "find the x-coordinates of the points where the gradient is 0": stop after step 3.
- **A quadratic curve**, such as $y = 1 + 8x - x^2$: $\frac{dy}{dx} = 8 - 2x = 0$ gives $x = 4$, $y = 17$, so the turning point is $(4, 17)$. (Completing the square, $y = 17 - (x-4)^2$, gets the same point.)
- **Answers to 1 or 2 decimal places:** keep the exact or full calculator values for x when you substitute to find y; round only at the end.
- **One turning point is given** and you need the other: solve $\frac{dy}{dx} = 0$ fully; the given x is one root, which is a useful check.

2. Find the derivative (10 questions)

1. Write any brackets out as separate terms first.
2. Apply "multiply by the power, take one off the power" to each term.
3. An x term becomes a number; a number term disappears.
4. Write the answer as $\dfrac{dy}{dx} = \ldots$ (not $y = \ldots$), and don't add extra terms or carry on differentiating.

For example, $y = 5x^2 - 3x + 2$ gives $\dfrac{dy}{dx} = 10x - 3$.

Variations you will meet: the question may say "differentiate", "find the derivative", "find $\dfrac{dy}{dx}$" or "find the gradient function". They all mean the same. For a function, "find the derivative of $h(x) = 3x^2 - 5x$" gives $6x - 5$.

3. Gradient at a given point (7 questions)

1. Differentiate.
2. **Substitute the x-value into $\dfrac{dy}{dx}$.** The number you get is the gradient.

For example, $y = 2x^3 - x$ at $x = -1$: $\frac{dy}{dx} = 6x^2 - 1 = 6 - 1 = 5$.

Variations you will meet: the point may be given as coordinates, such as $(2, 5)$: only the x-value goes into $\dfrac{dy}{dx}$. The question may not say "differentiate" at all: "find the gradient of the curve" always means differentiate first.

4. Maximum or minimum? (5 questions)

1. Find $\dfrac{d^2y}{dx^2}$ by differentiating $\dfrac{dy}{dx}$.
2. Substitute each turning point's x-value and **write the value**.
3. Conclude for **each** point: "$-12 < 0$, so $(-1, 10)$ is a maximum."

Variations you will meet:

- **Gradient either side:** choose x-values a little to each side (not past another turning point), work out $\dfrac{dy}{dx}$ at each, and state the signs.
- **"By sketching the graph, determine ...":** sketch the cubic (positive or negative x^3 term) with its turning points in the right quarters of the axes, then read off which is the hump and which the dip.
- **"Determine which one is a maximum"** with three turning points (a quartic): test all three, or use the sketch. For $y = x^4 - 18x^2 + 1$, $\frac{d^2y}{dx^2} = 12x^2 - 36$ is -36 at $x = 0$, so $(0, 1)$ is the maximum.

5. Equation of a tangent (5 questions)

1. Find the point of contact: if you only have x, substitute into the **curve** to get y.
2. Find the gradient m by substituting x into $\dfrac{dy}{dx}$.
3. Substitute the point into $y = mx + c$ to find c (or use $y - y_1 = m(x - x_1)$).
4. Write the answer as $y = mx + c$ with numbers.

For example, $y = x^2 - 10$ at $x = -2$: the point is $(-2, -6)$ and $\frac{dy}{dx} = 2x = -4$. Then $-6 = -4(-2) + c$, so $c = -14$ and the tangent is $y = -4x - 14$.

Variations you will meet:

- **"Show that the tangent is $y = \ldots$":** show every step (gradient, substitution, finding c) so the given line appears at the end.
- **A line perpendicular to the tangent** through a point (the normal, if it is at the same point): its gradient is $-\dfrac{1}{m}$. For a tangent with gradient 2, a perpendicular line has gradient $-\frac{1}{2}$.
- **Tangents with a given gradient:** see type 8.

6. Use the turning points: sketch, or count solutions (5 questions)

Sketching:

1. Decide the shape from the highest power and its sign (a positive cubic rises from bottom left to top right).
2. Put the turning points in the correct quarters of the axes, with the right one higher.
3. Mark where the curve crosses the axes if asked (y-intercept: put $x = 0$).
4. Draw one smooth curve with exactly those turning points: no extra wiggles.

"$f(x) = k$ has three solutions (or one, or fewer than three)":

1. Find the y-values of the maximum and minimum points, say $y_{\max}$ and $y_{\min}$.
2. Three solutions: $y_{\min} < k < y_{\max}$ (strict, the line must pass strictly between them).
3. Fewer than three: $k \geqslant y_{\max}$ or $k \leqslant y_{\min}$ (touching a turning point gives only two).
4. One solution only: $k > y_{\max}$ or $k < y_{\min}$. If the question wants whole numbers a and b such that there is one solution whenever $k < a$ or $k > b$, go outwards to the next integer: $y_{\min} = -3.2$ and $y_{\max} = 7.6$ give the largest $a = -4$ and the smallest $b = 8$.

7. Find unknown constants from the derivative (4 questions)

1. Differentiate the curve with the letters in it, treating them as numbers.
2. Use each fact you are given to write an equation:
   - "the gradient at $x = 1$ is 5": put $x = 1$ into $\frac{dy}{dx}$ and set it equal to 5;
   - "there is a turning point at $x = 2$": put $x = 2$ into $\frac{dy}{dx}$ and set it equal to 0;
   - "the point $(2, -1)$ is on the curve": put $x = 2$, $y = -1$ into the **curve's** equation.
3. Solve for the letters.

Variations you will meet:

- **The derivative is given**, such as "$y = px^3 + qx^2$ and $\frac{dy}{dx} = 12x^2 - 10x$". Differentiate: $3px^2 + 2qx$. Match coefficients: $3p = 12$, $2q = -10$, so $p = 4$, $q = -5$. If the power is unknown, $x^n \to nx^{n-1}$: a derivative with x^2 in it came from $n = 3$.
- **"Show that $k = \ldots$":** set the gradient equation up with k in it and solve; don't substitute the given k to check it.

8. Points where the gradient has a given value (2 questions)

1. Differentiate.
2. **Set $\dfrac{dy}{dx}$ equal to the given gradient** (not to 0) and solve. A quadratic usually gives two points.
3. Substitute each x into the curve's equation to get y.
4. If tangents are asked for, use each point and the given gradient in $y = mx + c$.

For example, on $y = x^3 - 6x + 2$ the gradient is 21 where $3x^2 - 6 = 21$, so $x^2 = 9$ and $x = \pm 3$. The points are $(3, 11)$ and $(-3, -7)$.

Worked examples

The bold codes show where marks are earned, as in Cambridge mark schemes. The number is how many marks.

- **M1** method mark: for a correct method, even if the numbers slip.
- **A1** accuracy mark: for a correct answer; it needs the M mark before it.
- **B1** mark for a correct result on its own, with no method needed.

Example 1

A curve has equation $y = 2x^3 - 5x^2 + 4$.

(a) Find $\dfrac{dy}{dx}$. **[2]**

(b) Find the gradient of the curve at the point where $x = 2$. **[2]**

(c) Find the equation of the tangent to the curve at the point where $x = 2$. Give your answer in the form $y = mx + c$. **[3]**

(a) $\dfrac{dy}{dx} = 6x^2 - 10x$. **B2** (**B1** for one correct term).

(b) $6(2)^2 - 10(2) = 24 - 20 = 4$. **M1** for substituting $x = 2$ into $\frac{dy}{dx}$, **A1**.

(c) At $x = 2$: $y = 2(8) - 5(4) + 4 = 0$, so the point is $(2, 0)$. **B1**

$0 = 4 \times 2 + c$, so $c = -8$. **M1** for using their gradient and point in $y = mx + c$.

$y = 4x - 8$. **A1**

Example 2

A curve has equation $y = x^3 - 3x^2 - 9x + 5$.

(a) Find the coordinates of the two turning points. You must show all your working. **[5]**

(b) Determine whether each turning point is a maximum or a minimum. Show how you decide. **[3]**

(c) The equation $x^3 - 3x^2 - 9x + 5 = k$ has three solutions. Find the range of values of k. **[2]**

(a) $\dfrac{dy}{dx} = 3x^2 - 6x - 9$. **B2**

$3x^2 - 6x - 9 = 0$ **M1**, so $x^2 - 2x - 3 = 0$ and $(x+1)(x-3) = 0$. **M1** for a correct method to solve.

$x = -1$: $y = -1 - 3 + 9 + 5 = 10$. $x = 3$: $y = 27 - 27 - 27 + 5 = -22$.

The turning points are $(-1, 10)$ and $(3, -22)$. **A1**

(b) $\dfrac{d^2y}{dx^2} = 6x - 6$. **M1**

At $x = -1$: $6(-1) - 6 = -12 < 0$, so $(-1, 10)$ is a **maximum**.

At $x = 3$: $6(3) - 6 = 12 > 0$, so $(3, -22)$ is a **minimum**. **B2** for both, each with its reason.

(c) The line $y = k$ must pass strictly between the two turning points (see the second diagram): $-22 < k < 10$. **B2** (**B1** for each end).

Example 3

The curve $y = x^3 + ax^2 + b$ has a turning point at $(2, -1)$.

(a) Find the value of a and the value of b. **[4]**

(b) Find the coordinates of the other turning point, and determine whether it is a maximum or a minimum. **[4]**

(a) $\frac{dy}{dx} = 3x^2 + 2ax$. **B1**

At $x = 2$ the gradient is 0: $12 + 4a = 0$, so $a = -3$. **M1 A1**

$(2, -1)$ is on the curve: $8 + 4(-3) + b = -1$, so $b = 3$. **B1**

(b) $y = x^3 - 3x^2 + 3$ and $\frac{dy}{dx} = 3x^2 - 6x = 3x(x-2) = 0$, so $x = 0$ or $x = 2$. **M1**

At $x = 0$: $y = 3$, so the other turning point is $(0, 3)$. **A1**

$\frac{d^2y}{dx^2} = 6x - 6 = -6 < 0$ at $x = 0$, so $(0, 3)$ is a **maximum**. **M1 A1**

(Check: at $x = 2$, $\frac{d^2y}{dx^2} = 6 > 0$, so $(2, -1)$ is the minimum. A positive cubic has its maximum on the left, which agrees.)

Example 4

A curve has equation $y = 2x^3 + 3x^2 - 6x + 1$.

(a) Find the x-coordinates of the turning points. Show all your working and give your answers correct to 2 decimal places. **[4]**

(b) Two tangents to the curve each have gradient 30. Find the equations of these two tangents. **[5]**

(a) $\frac{dy}{dx} = 6x^2 + 6x - 6$. **B1**

$6x^2 + 6x - 6 = 0$, so $x^2 + x - 1 = 0$. **M1**

$$x = \frac{-1 \pm \sqrt{1^2 - 4(1)(-1)}}{2(1)} = \frac{-1 \pm \sqrt{5}}{2}$$

M1 for the formula with the right values.

$x = 0.62$ and $x = -1.62$ (2 d.p.). **A1** (the full values are $0.618\ldots$ and $-1.618\ldots$).

(b) $6x^2 + 6x - 6 = 30$ **M1**, so $x^2 + x - 6 = 0$ and $(x+3)(x-2) = 0$: $x = 2$ or $x = -3$. **A1**

$x = 2$: $y = 16 + 12 - 12 + 1 = 17$. $x = -3$: $y = -54 + 27 + 18 + 1 = -8$. **B1** for both points.

$17 = 30(2) + c$ gives $c = -43$; $-8 = 30(-3) + c$ gives $c = 82$. **M1**

$y = 30x - 43$ and $y = 30x + 82$. **A1**

Common mistakes

- **Not multiplying by the power.** $-3x^2$ becomes $-6x$, not $-3x$. Multiply the coefficient by the power every time.
- **Mishandling the x term and the number.** $-x$ differentiates to -1 (not 0, and not $-2x$), and a number term such as $+8$ disappears rather than staying or becoming 1. Examiners see both every year.
- **Writing $y = \ldots$ for the derivative.** Write $\dfrac{dy}{dx} = \ldots$; the next line then makes sense to you and the examiner.
- **Not differentiating for a gradient.** Substituting x into the curve's equation gives a y-coordinate, not a gradient. Joining two points on the curve with a straight line doesn't give the gradient at a point either.
- **Setting the wrong thing equal to 0.** Turning points come from $\dfrac{dy}{dx} = 0$, never from $y = 0$ (those are the roots) or $\dfrac{d^2y}{dx^2} = 0$.
- **Losing $x = 0$ by dividing by x.** In $5x^2 - 2x = 0$, factorise to $x(5x - 2) = 0$: both $x = 0$ and $x = \frac{2}{5}$ count.
- **Finding y from the wrong equation.** The y-coordinate of a turning point comes from the curve, not from $\frac{dy}{dx}$ or $\frac{d^2y}{dx^2}$.
- **Using 0 instead of the given gradient.** If the gradient at $x = 1$ is 5, set $\frac{dy}{dx} = 5$, not 0.
- **A sketch that ignores your own answers.** The sketch must be the right shape (positive or negative cubic) with the turning points you found in the right places, and no extra humps.
- **A max/min conclusion with no reason**, or a reason for only one point. Each point needs its own evidence.
- **Rounding too early** when answers are asked to 1 or 2 decimal places. Use the full value of x when you work out y.

How to get the marks

- **Show the derivative.** Each correct term usually earns a mark on its own, and later method marks follow through from your derivative even if it is wrong. A correct answer that you then "spoil" (by adding a term or differentiating again) loses marks.
- **Write "$\dfrac{dy}{dx} = 0$"** when finding turning points. Stating it earns a method mark even before you solve.
- **"You must show all your working"** means differentiation must be seen. Answers found by a table of values or a graphic display score little or nothing.
- **"Find the coordinates"** means both x and y for every point.
- **"Determine" or "show how you decide"** for max/min means a reason and a conclusion for each point: the value of $\frac{d^2y}{dx^2}$ with its sign, the gradients either side with the x-values used, or a sketch that matches your points. Any wrong statement costs marks, so don't add guesses.
- **"Show that"** means the answer is printed. Show every step to reach it, and don't start from the answer.

- **Accuracy:** give exact values where you can. Otherwise use 3 significant figures, unless the question asks for something else, such as "correct to 2 decimal places".
- **Inequalities for k:** get the ends right and the signs right. "Three solutions" uses strict $<$; "fewer than three" includes the turning point values.

Quick check

1. Find $\frac{dy}{dx}$ when $y = 5x^4 - 2x^3 + 7x - 3$.
2. Find the gradient of the curve $y = x^3 - 4x^2 + 1$ at the point where $x = 3$.
3. Use differentiation to find the turning point of $y = 5 + 6x - x^2$, and state whether it is a maximum or a minimum.
4. Find the three turning points of $y = x^4 - 2x^2 + 3$ and decide the nature of each.
5. $y = ax^n + bx$ and $\frac{dy}{dx} = 20x^3 + 3$. Find a, n and b.

Answers

1. $\frac{dy}{dx} = 20x^3 - 6x^2 + 7$.
2. $\frac{dy}{dx} = 3x^2 - 8x$. At $x = 3$: $27 - 24 = 3$.
3. $\frac{dy}{dx} = 6 - 2x = 0$, so $x = 3$ and $y = 5 + 18 - 9 = 14$. $\frac{d^2y}{dx^2} = -2 < 0$, so $(3, 14)$ is a maximum.
4. $\frac{dy}{dx} = 4x^3 - 4x = 4x(x-1)(x+1) = 0$, so $x = 0, 1, -1$. The points are $(0, 3)$, $(1, 2)$ and $(-1, 2)$. $\frac{d^2y}{dx^2} = 12x^2 - 4$: at $x = 0$ it is $-4 < 0$, a maximum; at $x = \pm 1$ it is $8 > 0$, so both are minimums.
5. $\frac{dy}{dx} = anx^{n-1} + b$. Matching powers, $n - 1 = 3$, so $n = 4$. Matching coefficients, $4a = 20$, so $a = 5$, and $b = 3$.

Past questions to try

- **0580/43/M/J/23 Q12**: three turning points of a quartic, then which is the maximum.
- **0580/42/M/J/23 Q8**: sketching a cubic, then two tangents with a given gradient.
- **0580/43/M/J/22 Q9**: turning points to 2 decimal places, then when $f(x) = k$ has one solution.
- **0580/41/M/J/22 Q6**: gradient at a point, a zero gradient and constants from a derivative.