

# Lecture Notes for 2M1 – Q-STREAM

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**Course webpage:**

<http://www.maths.man.ac.uk/~mheil/Lectures/2M1>

## Note:

- This part of the course, dealing with functions of two variables and partial differential equations (PDEs), is taught during weeks 1-5.
- The course web page provides online access to the lecture notes, example sheets and other handouts and announcements.
- Most of the material will be taught in "chalk and talk" mode. If OHP transparencies are used, copies will be made available (after the lecture) on this page.
- Please consult the service course page

<http://www.maths.man.ac.uk/service>

for details on how to get hold of material for the other parts of the course.

- Please note that the lecture notes only summarise the main results and will generally be handed out *after* the material has been covered in the lecture. You are expected take notes during the classes.

# 1 Reminder: Functions of a single variable

A function  $y = y(x)$  is a function of a single variable.

## Examples

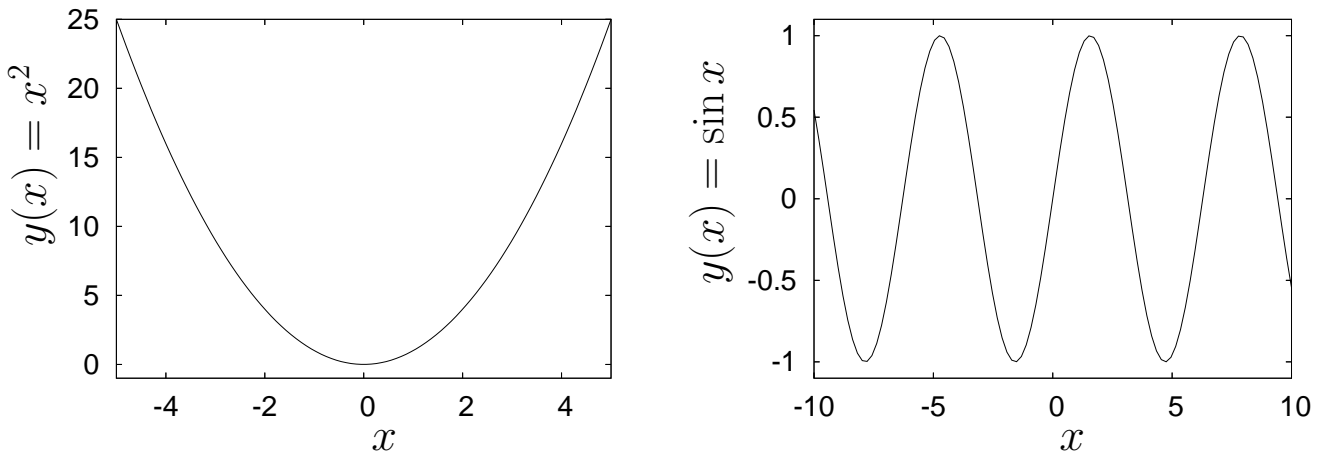


Figure 1: Functions of a single variable:  $y(x) = x^2$  and  $y(x) = \sin x$ .

## 1.1 [Ordinary] derivatives

**First derivative:**

$$y' = \frac{dy}{dx}$$

- The first derivative represents the slope of the curve  $y = y(x)$ .
- In general,  $y'$  is a function of  $x$  too.

**Second derivative:**

$$y'' = \frac{d^2y}{dx^2} = \frac{d}{dx} \left( \frac{dy}{dx} \right)$$

- The second derivative is the derivative of the first derivative.
- The second derivative indicates the curvature of the curve  $y = y(x)$ .

**Higher derivatives:**

$$y^{(n)} = \frac{d^n y}{dx^n} = \frac{d}{dx} \left( \frac{d}{dx} \left( \frac{d}{dx} \left( \dots \left( \frac{dy}{dx} \right) \dots \right) \right) \right)$$

- Higher derivatives are defined recursively: The  $n$ -th derivative is the derivative of the  $n - 1$ -th derivative.

## 1.2 Stationary points: Maxima and minima

**Condition for a stationary point:** .

- The function  $y(x)$  has a “stationary point” at  $x_0$  if

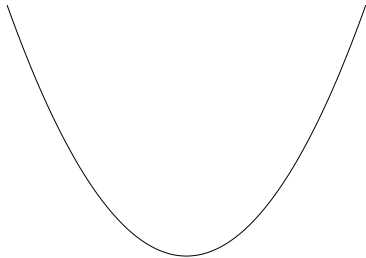
$$\left. \frac{dy}{dx} \right|_{x_0} = 0,$$

where the  $(...)|_{x_0}$  notation indicates that the expression in the round brackets is to be evaluated at  $x = x_0$ .

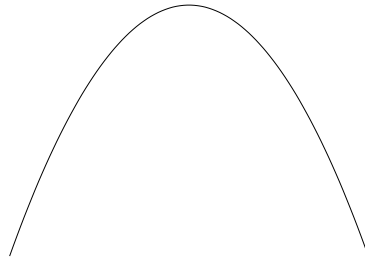
**Classification of stationary points:** .

- The nature of a stationary point is determined by the function’s second derivative:

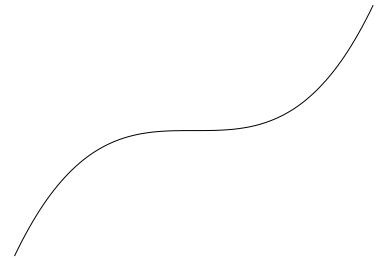
$$\left. \frac{d^2y}{dx^2} \right|_{x_0} \begin{cases} > 0 & \implies & \text{Local minimum} \\ < 0 & \implies & \text{Local maximum} \\ = 0 & \implies & \text{Test is not conclusive (curve too flat; e.g. at an inflection point.)} \end{cases}$$



(a) A local minimum



(b) A local maximum



(c) An inflection point

Figure 2: Generic stationary points for a function of one variable.

### 1.3 Taylor series:

- The Taylor series of a function  $y(x)$  about a point  $x = x_0$  provides an approximation of the function in the neighbourhood of  $x_0$ :

$$y(x_0 + \epsilon) = y(x_0) + \left. \frac{dy}{dx} \right|_{x_0} \epsilon + \frac{1}{2!} \left. \frac{d^2y}{dx^2} \right|_{x_0} \epsilon^2 + \frac{1}{3!} \left. \frac{d^3y}{dx^3} \right|_{x_0} \epsilon^3 + \dots$$

for “small”  $|\epsilon|$ .

Here  $n! = 1 \times 2 \times 3 \times \dots \times (n-1) \times n$  is the factorial.

The Taylor expansion may also be written as

$$y(x) = y(x_0) + \left. \frac{dy}{dx} \right|_{x_0} (x - x_0) + \frac{1}{2!} \left. \frac{d^2y}{dx^2} \right|_{x_0} (x - x_0)^2 + \frac{1}{3!} \left. \frac{d^3y}{dx^3} \right|_{x_0} (x - x_0)^3 + \dots$$

for “small” values of  $|x - x_0|$ .