Common mistakes in oblig 1

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Here are a few mistakes that were made repeatedly in the first mandatory assignment in *MAT2400*.

1 The mean value theorem

The mean value theorem states that if $f\colon [a,b] \to \mathbb{R}$ is continuously differentiable, then there is some $c \in (a,b)$ such that

$$f(b) - f(a) = f'(c)(b-a).$$

This is not true for vector-valued functions! That is, if $x\colon [0,1] \to \mathbb{R}^m$ is continuously differentiable and $s,t \in [0,1]$, then there might not exist some $\tau \in [0,1]$ such that

$$x(t) - x(s) = x'(\tau)(t-s).$$

Indeed, there might not even exist a τ such that $x'(\tau)$ is *parallel* to $x(t) - x(s)$.

2 Bounded sets vs. bounded elements

In problem 3b, you are asked to show that E_c is precompact, and if one uses Ascoli's theorem, the problem is to show that E_c is bounded and equicontinuous. Both of these are *uniform estimates*: **It is not enough** to show that each $x \in E_c$ is bounded and continuous, you need to show that these properties hold uniformly over all $x \in E_c$.

Let us take boundedness as an example. A single function $x \in E_c$ is *bounded* if there is some $M > 0$ such that

$$|x(t)| \leqslant M \qquad \forall\ t \in [0,1].$$

On the other hand, the set E_c is *bounded* if it is bounded in the sense of subsets of metric spaces: For some $y \in X$, there should exist some $R > 0$ such that

$$\rho(x,y) \leqslant R \qquad \forall\ x \in E_c,$$

where ρ is the supremum metric. Taking e.g. $y \equiv 0$, this is equivalent to the requirement that

$$|x(t)| \leqslant R \qquad \forall\ t \in [0,1],\ \forall\ x \in E_c.$$

Thus, the boundedness estimate should hold uniformly for all $x \in E_c$.

The [uniform] equicontinuity condition is also a uniform condition, in that the same value $\delta > 0$ in the definition of equicontinuity should work for every $x \in E_c$.

3 Writing and typesetting mathematics

For general tips on writing mathematics, you can consult my guide at `https://usf.fyi/writingmath/`.

3.1 Write more text than math

Your number one goal when writing mathematics is to communicate your ideas clearly to the reader. Try to put yourself in the reader's shoes: Is my text easy to read and understand, or is there something that can be done to improve readability?

The easiest way to make your text more readable is to write more English (or Norwegian). A good mathematical text almost always consists of more English words than mathematical symbols. In particular, *a sentence should never, ever consist of mathematical symbols only!* This is not to say that you should write long essays when solving problems, though. Adding small, simple words or phrases such as

> thus, hence, therefore, we see that, we know that, because, we have, so, define, assume that, ...

will improve readability immensely. Note also that a sentence should never start with a mathematical symbol:

$$x \text{ is a very big number}$$

is bad, but a simple rewriting will fix it:

$$\text{The number } x \text{ is very big.}$$

3.2 Write complete sentences

Every single sentence must consist of a subject and a verb, and in most cases an object. In principle, a mathematical symbol (such as $=$) can be a verb, but it is generally bad practice because it can lead to confusion.

Take the example

$$x = 5.$$

This is a complete sentence: The subject is x, the verb is $=$, and the object is 5. But as you now know, a sentence should never consist of only mathematical symbols. Thus, an improved version is

$$\text{The number } x = 5.$$

But this sentence is confusing: Is "$x = 5$" a definition? Or is the sentence a statement claiming a specific value of the number x? The confusion stems from having a mathematical symbol ($=$) as the main verb. Therefore, we should prefer the version

$$\text{The number } x \text{ equals } 5.$$

An alternative, perhaps more common version is

$$\text{We have } x = 5.$$

3.3 Don't use abbreviations

You should avoid using abbreviations, such as s.t. ("such that"). Long technical terms can be abbreviated, but explain the abbreviation at its first occurrence:

> We see that f is lsc. (lower semicontinuous).

Keep in mind that it is always more difficult for the reader to decode an abbreviation than to read the full expression. Therefore, think twice before you decide to abbreviate.

3.4 Punctuate correctly

Punctuation in mathematical text is simple, once you understand the following: A mathematical expression within a sentence *is part of that sentence.* Therefore, if a sentence ends with a mathematical expression, the expression should be followed by a period. For instance, note the period at the end of Euler's formula,

$$1 + e^{i\pi} = 0.$$

Similarly, if a mathematical expression sits in the middle of a sentence, such as

$$\int_0^\pi \cos x \, dx = 0,$$

then the expression should end with a comma, if that is appropriate.