

# REAL ANALYSIS QUALIFYING EXAMS

MINH KHA

**ABSTRACT.** Here are some of my own solutions of recent qualifying exams of Real Analysis in TAMU. For three exams Jan 2013, August 2012 and January 2012, I type all full solutions. For previous exams before 2012, I type solutions of some selected problems. Sometimes, there are some comments and similar exercises after some problems. This is written for my Real Analysis Qualifying Exam Preparation Course in Summer 2013 at TAMU.

## 1. JANUARY 2013

**Problem 1:** Let  $f$  be a Lebesgue integrable, real valued function on  $(0, 1)$  and for  $x \in (0, 1)$  define

$$g(x) = \int_x^1 t^{-1} f(t) dt \quad (1)$$

Show that  $g$  is Lebesgue integrable and  $\int_0^1 g(x) dx = \int_0^1 f(x) dx$ .

*Proof.* Since  $f(t)/t$  is measurable, we could approximate it by a sequence of simple functions on  $(0, 1)$ . Hence,  $g$  is Lebesgue measurable. Applying Fubini theorem for  $t^{-1}|f(t)|$ ,

$$\int_0^1 |g(x)| dx \leq \int_0^1 \int_x^1 |t^{-1} f(t)| dt dx = \int_0^1 t^{-1} |f(t)| \int_0^t dx dt = \|f\|_1 < \infty \quad (2)$$

Thus  $g$  is Lebesgue integrable.

The identity (1) is proved by Fubini theorem again since  $g$  is integrable now.  $\square$

**Problem 2:** Let  $f_n \in C[0, 1]$ . Show that  $f_n \rightarrow 0$  weakly if and only if the sequence  $(\|f_n\|)_{n=1}^{\infty}$  is bounded and  $f_n$  converges pointwise to 0.

*Proof.*  $f_n \rightarrow 0$  weakly iff for any nonnegative Borel measure  $\mu$  on  $[0, 1]$ , then

$$\int_0^1 f_n d\mu \rightarrow 0 \quad (3)$$

Moreover,  $f_n$  converges pointwise to 0 iff for any  $x_0 \in [0, 1]$ , (3) is satisfied for  $\mu = \delta_{x_0}$ .

Assume (3). Since  $L^1[0, 1]^* = L^\infty[0, 1]$ ,  $\|f_n\| = \sup_{\|g\|_1 \leq 1} |\int_0^1 f_n g dx|$ . If we view each  $f_n$  as a linear functional on  $L^1[0, 1]$  and since  $\sup_n |\int_0^1 f_n g dx| < \infty$  for each

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