



## Complex Integrals

### 1 Why

TODO We extend integrability to complex functions.

### 2 Definition

A *measurable* complex-valued function on a measurable space is one whose real and imaginary parts are both measurable. A *integrable* complex-valued function on a measurable space is one whose real and imaginary parts are both integrable. called measurable if its real and imaginary parts are measurable.

The *integral* of a integrable complex-valued function on a measurable space is the complex number whose real part is the integral of the real part of the function and whose imaginary part is the integral imaginary part of the function.

#### 2.1 Notation

Let  $(X, \mathcal{A}, \mu)$  be a measure space. Let  $C$  denote the set of complex numbers. Let  $f : X \rightarrow C$  be a function.  $f$  is measurable if  $\mathbf{Re}(f)$  and  $\mathbf{Im}(f)$  are measurable.  $f$  is integrable if  $\mathbf{Re}(f)$  and  $\mathbf{Im}(f)$  is integrable. If  $f$  is integrable, we denote its integral by  $\int f d\mu$ . We have defined it by:

$$\int f d\mu = \int \mathbf{Re}(f) d\mu + i \int \mathbf{Im}(f) d\mu.$$

### 3 Results

**Proposition 1.** *A linear combination of two integrable complex-valued functions is an integrable complex-valued function.*

**Proposition 2.** *The integral is a linear operator on the vector space of integrable complex-valued functions.*

**Proposition 3.** *The absolute value of the integral of a complex-valued function is smaller than the integral of the absolute value of the function.*

*Proof.* Let  $(X, \mathcal{A}, \mu)$  be a measure space. Let  $C$  denote the complex numbers. Let  $f : X \rightarrow C$  integrable. There exists  $\alpha \in C$  with  $|\alpha| = 1$  such that

$$\left| \int f d\mu \right| = \alpha \int f d\mu.$$

Since the integral is homogenous,

$$\left| \int f d\mu \right| = \int \alpha f d\mu = \int \mathbf{Re}(\alpha f) d\mu + i \int \mathbf{Im}(\alpha f) d\mu.$$

Since  $\left| \int f d\mu \right|$  is real,  $\int \mathbf{Im}(\alpha f) d\mu = 0$ , so

$$\left| \int f d\mu \right| = \int \mathbf{Re}(\alpha f) d\mu \leq \int |\alpha f| d\mu = \int |f| d\mu,$$

since  $\mathbf{Re}(z) \leq |z|$  for all complex numbers  $z$  and  $|\alpha| = 1$ . □