

# Package ‘expint’

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**Type** Package

**Title** Exponential Integral and Incomplete Gamma Function

**Version** 0.1-5

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**Description** The exponential integrals  $E_1(x)$ ,  $E_2(x)$ ,  $E_n(x)$  and  $Ei(x)$ , and the incomplete gamma function  $G(a, x)$  defined for negative values of its first argument. The package also gives easy access to the underlying C routines through an API; see the package vignette for details. A test package included in sub-directory `example_API` provides an implementation. C routines derived from the GNU Scientific Library <<https://www.gnu.org/software/gsl/>>.

**Depends** R (>= 3.3.0)

**License** GPL (>= 2)

**URL** <https://github.com/vigou3/expint>

**BugReports** <https://github.com/vigou3/expint/issues>

**Encoding** UTF-8

**LazyLoad** yes

**LazyData** yes

**NeedsCompilation** yes

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expint-package      *Exponential Integral and Incomplete Gamma Function*

### Description

The exponential integrals  $E_1(x)$ ,  $E_2(x)$ ,  $E_n(x)$  and  $Ei(x)$ , and the incomplete gamma function  $\Gamma(a, x)$  that is defined for negative values of its first argument.

### Details

The exponential integral

$$E_1(x) = \int_x^\infty \frac{e^{-t}}{t} dt$$

and the incomplete gamma function

$$\Gamma(a, x) = \int_x^\infty t^{a-1} e^{-t} dt$$

are closely related functions that arise in various fields of mathematics.

**expint** is a small package that provides R functions to compute the exponential integral and the incomplete gamma function.

Most conveniently for R package developers, the package also gives access to the underlying C workhorses through an API; see the package vignette for instructions.

The C routines are adapted versions of those of the GNU Scientific Library <https://www.gnu.org/software/gsl/>.

### Author(s)

Vincent Goulet <vincent.goulet@act.ulaval.ca>

### References

Abramowitz, M. and Stegun, I. A. (1972), *Handbook of Mathematical Functions*, Dover.

### See Also

[expint](#) for the exponential integral family of functions.

[gammainc](#) for the incomplete gamma function.

`vignette("expint")` for a detailed presentation of the package.

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expint	<i>Exponential Integral</i>
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### Description

The exponential integrals  $E_1(x)$ ,  $E_2(x)$ ,  $E_n(x)$  and  $Ei$ .

### Usage

```
expint(x, order = 1L, scale = FALSE)
expint_E1(x, scale = FALSE)
expint_E2(x, scale = FALSE)
expint_En(x, order, scale = FALSE)
expint_Ei(x, scale = FALSE)
```

### Arguments

x	vector of real numbers.
order	vector of non-negative integers; see Details.
scale	logical; when TRUE the result will be scaled by $e^x$ .

### Details

Abramowitz and Stegun (1972) first define the exponential integral as

$$E_1(x) = \int_x^\infty \frac{e^{-t}}{t} dt, \quad x \neq 0.$$

An alternative definition (to be understood in terms of the Cauchy principal value due to the singularity of the integrand at zero) is

$$Ei(x) = - \int_{-x}^\infty \frac{e^{-t}}{t} dt = -E_1(-x).$$

The exponential integral can also be generalized to order  $n$  as

$$E_n(x) = \int_1^\infty \frac{e^{-xt}}{t^n} dt,$$

for  $n = 0, 1, 2, \dots$ ;  $x$  a real number (non-negative when  $n > 2$ ).

The following relation holds:

$$E_n(x) = x^{n-1} \Gamma(1-n, x),$$

where  $\Gamma(a, x)$  is the incomplete gamma function implemented in [gammainc](#).

By definition,  $E_0(x) = x^{-1}e^{-x}$ ,  $x \neq 0$ .

Function `expint` is vectorized in both `x` and `order`, whereas function `expint_En` expects a single value for `order` and will only use the first value if `order` is a vector.

Non-integer values of `order` will be silently coerced to integers using truncation towards zero.

**Value**

The value of the exponential integral.

Invalid arguments will result in return value NaN, with a warning.

**Note**

The C implementation is based on code from the GNU Software Library <https://www.gnu.org/software/gsl/>.

**Author(s)**

Vincent Goulet <vincent.goulet@act.ulaval.ca>

**References**

Abramowitz, M. and Stegun, I. A. (1972), *Handbook of Mathematical Functions*, Dover.

**See Also**

[gammainc](#)

**Examples**

```
## See section 5.3 of Abramowitz and Stegun
expint(1.275, order = 1:10)
expint(10, order = 1:10) * 1e5
expint(c(1.275, 10), order = c(1, 2))

expint_E1(1.275)           # same as above
expint_E2(10)             # same as above

## Figure 5.1 of Abramowitz and Stegun
curve(expint_Ei, xlim = c(0, 1.6), ylim = c(-3.9, 3.9),
      ylab = "y")
abline(h = 0)
curve(expint_E1, add = TRUE)
x <- 1.5
text(x, c(expint_Ei(x), expint_E1(x)),
     expression(Ei(x), E[1](x)),
     adj = c(0.5, -0.5))

## Figure 5.2 of Abramowitz and Stegun
plot(NA, xlim = c(-1.6, 1.6), ylim = c(0, 1),
     xlab = "x", ylab = expression(E[n](x)))
n <- c(10, 5, 3, 2, 1, 0)
for (order in n)
  curve(expint_En(x, order), add = TRUE)
x <- c(0.1, 0.15, 0.25, 0.35, 0.5, 0.7)
text(x, expint(x, n), paste("n =", n),
     adj = c(-0.2, -0.5))
```

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`gammainc`*Incomplete Gamma Function*

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**Description**

The incomplete gamma function  $\Gamma(a, x)$ .

**Usage**

```
gammainc(a, x)
```

**Arguments**

<code>a</code>	vector of real numbers.
<code>x</code>	vector of non-negative real numbers.

**Details**

As defined in 6.5.3 of Abramowitz and Stegun (1972), the incomplete gamma function is

$$\Gamma(a, x) = \int_x^{\infty} t^{a-1} e^{-t} dt$$

for  $a$  real and  $x \geq 0$ .

For non-negative values of  $a$ , we have

$$\Gamma(a, x) = \Gamma(a)(1 - P(a, x)),$$

where  $\Gamma(a)$  is the function implemented by R's `gamma()` and  $P(a, x)$  is the cumulative distribution function of the gamma distribution (with scale equal to one) implemented by R's `pgamma()`.

Also,  $\Gamma(0, x) = E_1(x)$ ,  $x > 0$ , where  $E_1(x)$  is the exponential integral implemented in `expint`.

**Value**

The value of the incomplete gamma function.

Invalid arguments will result in return value NaN, with a warning.

**Note**

The C implementation is based on code from the GNU Software Library <https://www.gnu.org/software/gsl/>.

**Author(s)**

Vincent Goulet <vincent.goulet@act.ulaval.ca>

**References**

Abramowitz, M. and Stegun, I. A. (1972), *Handbook of Mathematical Functions*, Dover.

**See Also**

[expint](#)

**Examples**

```
## a > 0
x <- c(0.2, 2.5, 5, 8, 10)
a <- 1.2
gammainc(a, x)
gamma(a) * pgamma(x, a, 1, lower = FALSE) # same

## a = 0
a <- 0
gammainc(a, x)
expint(x) # same

## a < 0
a <- c(-0.25, -1.2, -2)
sapply(a, gammainc, x = x)
```

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