

# Advanced Engineering Mathematics Complex Analysis by Dennis G. Zill Problems

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## 17 Functions of a Complex Variable

### 17.1 Complex Numbers

17.1.1

$$3 + 3i$$

17.1.3

$$i^8 = (i^2)^4 = (-1)^4 = 1$$

17.1.5

$$7 - 13i$$

17.1.7

$$-7 + 5i$$

17.1.9

$$11 - 10i$$

17.1.11

$$-5 + 12i$$

17.1.13

$$-2i$$

17.1.15

$$\begin{aligned}\frac{2 - 4i}{3 + 5i} &= \frac{(2 - 4i)(3 - 5i)}{34} \\ &= \frac{-14 - 22i}{34} \\ &= -\frac{7}{17} - \frac{11}{17}i\end{aligned}$$

**17.1.17**

$$\begin{aligned}\frac{(3-i)(2+3i)}{1+i} &= \frac{9+7i}{1+i} \\ &= \frac{(9+7i)(1-i)}{2} \\ &= \frac{16-2i}{2} \\ &= 8-i\end{aligned}$$

**17.1.27**

$$\begin{aligned}\frac{1}{z} &= \frac{\bar{z}}{z\bar{z}} \\ &= \frac{x-iy}{x^2+y^2} \\ \operatorname{Re}\left(\frac{1}{z}\right) &= \frac{x}{x^2+y^2}\end{aligned}$$

**17.1.29**

$$\begin{aligned}2z + 4\bar{z} - 4i &= 2(x+iy) + 4(x-iy) - 4i \\ &= 6x - 2(y+2)i \\ \operatorname{Im}(2z + 4\bar{z} - 4i) &= -2y - 4\end{aligned}$$

**17.1.31**

$$\begin{aligned}z - 1 - 3i &= x + iy - 1 - 3i \\ &= (x-1) + (y-3)i \\ |z| &= \sqrt{(x-1)^2 + (y-3)^2}\end{aligned}$$

**17.1.33**

$$\begin{aligned}2z &= i(2+9i) \\ &= -9+2i \\ z &= -\frac{9}{2} + i\end{aligned}$$

**17.1.35**

$$\begin{aligned}
(x + iy)^2 &= x^2 + 2xyi - y^2 \\
&= (x^2 - y^2) + 2xyi \\
x^2 &= y^2 \\
x &= y \\
2xy &= 1 \\
x^2 &= \frac{1}{2} \\
x &= \frac{\sqrt{2}}{2} \\
z &= \frac{\sqrt{2}}{2}(1 + i)
\end{aligned}$$

**17.1.37**

$$\begin{aligned}
z + 2\bar{z} &= x + iy + 2x - 2iy \\
&= 3x - iy \\
\frac{2 - i}{1 + 3i} &= \frac{(2 - i)(1 - 3i)}{10} \\
&= \frac{-1 - 7i}{10} \\
3x - iy &= \frac{-1 - 7i}{10} \\
x &= -\frac{1}{30} \\
y &= \frac{7}{10} \\
z &= -\frac{1}{30} + \frac{7}{10}i
\end{aligned}$$

**17.1.39**

$$\begin{aligned}
|10 + 8i| &\approx 12.8 \\
|11 - 6i| &\approx 12.5
\end{aligned}$$

$11 - 6i$  is closer.

**17.2 Powers and Roots****17.2.1**

$$2(\cos 0 + i \sin 0)$$

**17.2.3**

$$-3[\cos(-\pi/2) + i \sin(-\pi/2)]$$

**17.2.5**

$$\sqrt{2}[\cos(\pi/4) + i \sin(\pi/4)]$$

**17.2.7**

$$2[\cos(5\pi/6) + i \sin(5\pi/6)]$$

**17.2.9**

$$\begin{aligned}\frac{3}{-1+i} &= \frac{3(-1-i)}{2} \\ &= \frac{-3-3i}{2} \\ &= -\frac{3}{2} - \frac{3}{2}i \\ &= \frac{3\sqrt{2}}{2}[\cos(5\pi/4) + i \sin(5\pi/4)]\end{aligned}$$

**17.2.11**

$$-\frac{5\sqrt{3}}{2} - \frac{5}{2}i$$

**17.2.13**

$$5.54 + 2.30i$$

**17.2.15**

$$\begin{aligned}8[\cos(\pi/2) + i \sin(\pi/2)] &= 8i \\ \frac{1}{2}[\cos(-\pi/4) + i \sin(-\pi/4)] &= \frac{\sqrt{2}}{4} - \frac{\sqrt{2}}{4}i\end{aligned}$$

**17.2.21**

$$\begin{aligned}(1 + \sqrt{3}i)^9 &= \{2[\cos(\pi/3) + i \sin(\pi/3)]\}^9 \\ &= 512(\cos \pi + i \sin \pi) \\ &= -512\end{aligned}$$

**17.2.23**

$$\begin{aligned}\left(\frac{1}{2} + \frac{1}{2}i\right)^{10} &= \left\{ \frac{\sqrt{2}}{2} [\cos(\pi/4) + i \sin(\pi/4)] \right\}^{10} \\ &= \frac{1}{32} [\cos(\pi/2) + i \sin(\pi/2)] \\ &= \frac{1}{32}i\end{aligned}$$

**17.2.27**

$$\begin{aligned}w_k &= 2[\cos(2\pi k/3) + i \sin(2\pi k/3)] \\ w_0 &= 2 \\ w_1 &= -1 + \sqrt{3}i \\ w_2 &= -1 - \sqrt{3}i\end{aligned}$$

**17.2.29**

$$\begin{aligned}w_k &= \cos(\pi/4 + k\pi) + i \sin(\pi/4 + k\pi) \\ w_0 &= \frac{\sqrt{2}}{2}(1 + i) \\ w_1 &= -\frac{\sqrt{2}}{2}(1 + i)\end{aligned}$$

**17.2.31**

$$\begin{aligned}w_k &= \sqrt{2}[\cos(\pi/3 + k\pi) + i \sin(\pi/3 + k\pi)] \\ w_0 &= \frac{\sqrt{2}}{2} + \frac{\sqrt{6}}{2}i \\ w_1 &= -\frac{\sqrt{2}}{2} - \frac{\sqrt{6}}{2}i\end{aligned}$$



**17.2.33**

$$z^4 + 1 = 0$$

$$z^4 = -1$$

$$w_k = \cos(\pi/4 + k\pi/2) + \sin(\pi/4 + k\pi/2)i$$

$$w_0 = \frac{\sqrt{2}}{2} + \frac{\sqrt{2}}{2}i$$

$$w_1 = -\frac{\sqrt{2}}{2} + \frac{\sqrt{2}}{2}i$$

$$w_2 = -\frac{\sqrt{2}}{2} - \frac{\sqrt{2}}{2}i$$

$$w_3 = \frac{\sqrt{2}}{2} - \frac{\sqrt{2}}{2}i$$

**17.3 Sets in the Complex Plane****17.3.1**

A vertical line at  $\operatorname{Re}(z) = 5$ .

**17.3.3**

A horizontal line at  $\operatorname{Im}(z) = -3$ .

**17.3.5**

A circle of radius 2 centred at  $3i$ .

**17.3.7**

A circle of radius 5 centred at  $4 - 3i$ .

**17.3.9**

The region of the plane to the left of (but not including)  $\operatorname{Re}(z) = -1$ . It is a domain.

**17.3.11**

The region of the plane above (but not including)  $\operatorname{Im}(z) = 3$ . It is a domain.

**17.3.13**

The region of the plane between (but not including)  $\operatorname{Re}(z) = 3$  and  $\operatorname{Re}(z) = 5$ . It is a domain.

**17.3.15**

$$\begin{aligned}
z^2 &= (a + ib)^2 \\
&= a^2 - b^2 + 2iab \\
\operatorname{Re}(z^2) &= a^2 - b^2 \\
\operatorname{Re}(z^2) &> 0 \\
a^2 - b^2 &> 0 \\
a^2 &> b^2
\end{aligned}$$

The region between  $y = x$  and  $y = -x$ . Not a domain.

**17.3.17**

The region between  $\theta = 0$  and  $\theta = 2\pi/3$ . Not a domain.

**17.3.19**

The region outside a circle of radius 1 centred at  $i$ . It is a domain.

**17.3.21**

The region between the circles of radius 2 and 3 centred at  $i$ . It is a domain.

**17.3.23**

$$y = -x$$

**17.3.25**

$$\begin{aligned}
z^2 + \bar{z}^2 &= (a + ib)^2 + (a - ib)^2 \\
&= a^2 + 2iab - b^2 + a^2 - 2iab - b^2 \\
&= 2(a^2 - b^2) \\
2(a^2 - b^2) &= 2 \\
a^2 - b^2 &= 1 \\
a^2 &= b^2 + 1
\end{aligned}$$

The hyperbola  $x^2 - y^2 = 1$ .

## 17.4 Functions of a Complex Variable

### 17.4.1

$$\begin{aligned}f(z) &= z^2 \\&= (x + iy)^2 \\&= x^2 - y^2 + 2ixy \\u(x, y) &= x^2 - y^2 \\&= x^2 - 4 \\v(x, y) &= 2xy \\&= 4x \\x &= \frac{v}{4} \\u &= \left(\frac{v}{4}\right)^2 - 4 \\&= \frac{1}{16}v^2 - 4\end{aligned}$$

### 17.4.3

$$\begin{aligned}u &= -y^2 \\v &= 0\end{aligned}$$

Line on the left half of the real axis.

### 17.4.5

$$\begin{aligned}u &= 0 \\v &= 2x^2\end{aligned}$$

Line on the top half of the imaginary axis.

### 17.4.7

$$f(x) = (6x - 5) + i(6y + 9)$$

### 17.4.9

$$f(z) = (x^2 - y^2 - 3x) + i(2xy - 3y + 4)$$

### 17.4.11

$$f(z) = (x^3 - 3xy^2 - 4x) + i(3x^2y - y^3 - 4y)$$

**17.4.13**

$$f(z) = \left(x + \frac{x}{x^2 + y^2}\right) i \left(y - \frac{y}{x^2 + y^2}\right)$$

**17.4.15**

(a)  $-4 + i$

(b)  $3 - 9i$

(c)  $1 + 86i$

**17.4.17**

(a)  $14 - 20i$

(b)  $-13 + 43i$

(c)  $3 - 26i$

**17.4.19**

$$6 - 5i$$

**17.4.21**

$$-4i$$

**17.4.27**

$$f'(z) = 12z^2 - 2(3 + i)z - 5$$

**17.4.29**

$$\begin{aligned} f'(z) &= 2(z^2 - 4z + 8i) + (2z + 1)(2z - 4) \\ &= 2z^2 - 8z + 16i + 4z^2 - 8z + 2z - 4 \\ &= 6z^2 - 14z - 4 + 16i \end{aligned}$$

**17.4.31**

$$f'(z) = 6z(z^2 - 4i)^2$$

**17.4.33**

$$\begin{aligned}f'(z) &= \frac{3(2z+i) - 2(3z-4+8i)}{(2z+i)^2} \\&= \frac{6z+3i-6z+8-16i}{(2z+i)^2} \\&= \frac{8-13i}{(2z+i)^2}\end{aligned}$$

**17.4.35**

$$3i$$

**17.4.37**

$$\pm 2i$$

**17.4.41**

$$\begin{aligned}\frac{dx}{dt} &= 2x \\x &= c_1 e^{2t} \\ \frac{dy}{dt} &= 2y \\y &= c_2 e^{2t}\end{aligned}$$

### 17.4.43

$$\begin{aligned}f(z) &= \frac{1}{\bar{z}} \\&= \frac{1}{x - iy} \\&= \frac{x + iy}{x^2 + y^2} \\&= \frac{x}{x^2 + y^2} + i \frac{y}{x^2 + y^2} \\ \frac{dx}{dt} &= \frac{x}{x^2 + y^2} \\ \frac{dy}{dt} &= \frac{y}{x^2 + y^2} \\ \frac{dy}{dx} &= \frac{y}{x} \\ \frac{dy}{y} &= \frac{dx}{x} \\ \ln y &= \ln x + c_1 \\ y &= c_2 x\end{aligned}$$

## 17.5 Cauchy-Riemann Equations

### 17.5.1

$$\begin{aligned}f(z) &= z^3 \\&= (x + iy)^3 \\&= (x^2 + 2ixy - y^2)(x + iy) \\&= x^3 + ix^2y + 2ix^2y - 2xy^2 - xy^2 - iy^3 \\&= (x^3 - 3xy^2) + i(3x^2y - y^3) \\ \frac{\partial u}{\partial x} &= 3x^2 - 3y^2 \\&= \frac{\partial v}{\partial y} \\ \frac{\partial u}{\partial y} &= -6xy \\&= -\frac{\partial v}{\partial x}\end{aligned}$$

**17.5.3**

$$\begin{aligned}
f(z) &= \operatorname{Re}(z) \\
&= x \\
\frac{\partial u}{\partial x} &= 1 \\
&\neq \frac{\partial v}{\partial y}
\end{aligned}$$

**17.5.5**

$$\begin{aligned}
f(z) &= 4z - 6\bar{z} + 3 \\
&= 4(x + iy) - 6(x - iy) + 3 \\
&= (-2x + 3) + 10iy \\
\frac{\partial u}{\partial x} &= -2 \\
&\neq \frac{\partial v}{\partial y}
\end{aligned}$$

**17.5.7**

$$\begin{aligned}
f(z) &= x^2 + y^2 \\
\frac{\partial u}{\partial x} &= 2x \\
&\neq \frac{\partial v}{\partial y}
\end{aligned}$$

**17.5.9**

$$\begin{aligned}
f(z) &= e^x \cos y + ie^x \sin y \\
u &= e^x \cos y \\
\frac{\partial u}{\partial x} &= e^x \cos y \\
\frac{\partial u}{\partial y} &= -e^x \sin y \\
v &= e^x \sin y \\
\frac{\partial v}{\partial x} &= e^x \sin y \\
\frac{\partial v}{\partial y} &= e^x \cos y
\end{aligned}$$

Analytic everywhere.

**17.5.11**

$$f(z) = x + \sin x \cosh y + i(y + \cos x \sinh y)$$

$$u = x + \sin x \cosh y$$

$$\frac{\partial u}{\partial x} = 1 + \cos x \cosh y$$

$$\frac{\partial u}{\partial y} = \sin x \sinh y$$

$$v = y + \cos x \sinh y$$

$$\frac{\partial v}{\partial x} = -\sin x \sinh y$$

$$\frac{\partial v}{\partial y} = 1 + \cos x \cosh y$$

Analytic everywhere.

**17.5.15**

$$f(z) = 3x - y + 5 + i(ax + by - 3)$$

$$u = 3x - y + 5$$

$$\frac{\partial u}{\partial x} = 3$$

$$\frac{\partial u}{\partial y} = -1$$

$$v = ax + by - 3$$

$$\frac{\partial v}{\partial x} = a$$

$$\frac{\partial v}{\partial y} = b$$

$$a = 1$$

$$b = 3$$



**17.5.17**

$$f(z) = x^2 + y^2 + 2ixy$$

$$u = x^2 + y^2$$

$$\frac{\partial u}{\partial x} = 2x$$

$$\frac{\partial u}{\partial y} = 2y$$

$$v = 2xy$$

$$\frac{\partial v}{\partial x} = 2y$$

$$\frac{\partial v}{\partial y} = 2x$$

Only differentiable when  $y = 0$ .

**17.5.19**

$$f(z) = x^3 + 3xy^2 - x + i(y^3 + 3x^2y - y)$$

$$u = x^3 + 3xy^2 - x$$

$$\frac{\partial u}{\partial x} = 3x^2 + 3y^2 - 1$$

$$\frac{\partial u}{\partial y} = 6xy$$

$$v = y^3 + 3x^2y - y$$

$$\frac{\partial v}{\partial x} = 6xy$$

$$\frac{\partial v}{\partial y} = 3y^2 + 3x^2 - 1$$

Only differentiable when  $x = 0$  or  $y = 0$ .

**17.5.21**

$$f(z) = e^x \cos y + ie^x \sin y$$

$$\begin{aligned} f'(z) &= \frac{\partial u}{\partial x} + i \frac{\partial v}{\partial x} \\ &= e^x \cos y + ie^x \sin y \end{aligned}$$

**17.5.23**

$$\begin{aligned}
u &= x \\
\frac{\partial^2 u}{\partial x^2} &= 0 \\
\frac{\partial^2 u}{\partial y^2} &= 0 \\
\frac{\partial v}{\partial y} &= 1 \\
v &= y + h(x) \\
h'(x) &= 0 \\
v &= y + c \\
f(z) &= x + i(y + c)
\end{aligned}$$

**17.5.25**

$$\begin{aligned}
u &= x^2 - y^2 \\
\frac{\partial^2 u}{\partial x^2} &= 2 \\
\frac{\partial^2 u}{\partial y^2} &= -2 \\
\frac{\partial v}{\partial y} &= 2x \\
v &= 2xy + h(x) \\
2y &= 2y + h'(x) \\
h'(x) &= 0 \\
h(x) &= c \\
v &= 2xy + c \\
f(z) &= (x^2 - y^2) + i(2xy + c)
\end{aligned}$$

**17.6 Exponential and Logarithmic Functions****17.6.1**

$$\frac{\sqrt{3}}{2} + \frac{1}{2}i$$

**17.6.3**

$$e^{-1} \frac{\sqrt{2}}{2} (1 + i)$$

**17.6.5**

$$-e^{\pi}$$

**17.6.7**

$$e^{1.5}(\cos 2 + i \sin 2) = -1.865 + 4.075i$$

**17.6.9**

$$\cos 5 + i \sin 5 = 0.2836 - 0.9589i$$

**17.6.11**

$$\begin{aligned} e^{1+5\pi i/4} e^{-1-\pi i/3} &= e^{11\pi i/12} \\ &= \cos \frac{11\pi}{12} + i \sin \frac{11\pi}{12} \\ &= -0.9659 + 0.2588i \end{aligned}$$

**17.6.13**

$$\begin{aligned} f(z) &= e^{-iz} \\ &= e^{-i(x+iy)} \\ &= e^{y-ix} \\ &= e^y(\cos x - i \sin x) \end{aligned}$$

**17.6.15**

$$\begin{aligned} f(z) &= e^{z^2} \\ &= e^{x^2-y^2+2ixy} \\ &= e^{x^2-y^2}[\cos(2xy) + i \sin(2xy)] \end{aligned}$$

**17.6.17**

$$\begin{aligned} e^z &= e^{x+iy} \\ &= e^x(\cos y + i \sin y) \\ |e^z| &= \sqrt{e^{2x}[\cos^2 y + \sin^2 y]} \\ &= e^x \end{aligned}$$

**17.6.19**

$$\begin{aligned}e^{z+\pi i} &= e^{x+i(y+\pi)} \\&= e^x[\cos(y+\pi) + i\sin(y+\pi)] \\&= e^x[-\cos y - i\sin y] \\&= -e^x(\cos y + i\sin y) \\e^{z-\pi i} &= e^{x+i(y-\pi)} \\&= e^x[\cos(y-\pi) + i\sin(y-\pi)] \\&= e^x(-\cos y - i\sin y) \\&= -e^x(\cos y + i\sin y)\end{aligned}$$

**17.6.21**

$$\begin{aligned}e^{\bar{z}} &= e^{x-iy} \\&= e^x(\cos y - i\sin y) \\u &= e^x \cos y \\v &= -e^x \sin y \\\frac{\partial u}{\partial x} &= e^x \cos y \\&\neq \frac{\partial v}{\partial y}\end{aligned}$$

**17.6.23**

$$\log_e 5 + i(\pi + 2n\pi) = 1.6094 + i(\pi + 2n\pi)$$

**17.6.25**

$$\log_e(2\sqrt{2}) + i\left(\frac{3}{4}\pi + 2n\pi\right) = 1.0397 + i\left(\frac{3}{4}\pi + 2n\pi\right)$$

**17.6.27**

$$\log_e(2\sqrt{2}) + i\left(\frac{1}{3}\pi + 2n\pi\right) = 1.0397 + i\left(\frac{1}{3}\pi + 2n\pi\right)$$

**17.6.29**

$$\log_e(6\sqrt{2}) - \frac{\pi}{4}i = 2.1383 - \frac{\pi}{4}i$$

**17.6.31**

$$\log_e 13 + 2.7468i = 2.5649 + 2.7468i$$

**17.6.33**

$$5 \left( \log_e 2 + \frac{\pi}{3} i \right) = 3.4657 - \frac{\pi}{3} i$$

**17.6.35**

$$z = \log_e 4 + i \left( \frac{\pi}{2} + 2n\pi \right) = 1.3863 + i \left( \frac{\pi}{2} + 2n\pi \right)$$

**17.6.37**

$$\begin{aligned} z - 1 &= 2 + i \left( -\frac{\pi}{2} + 2n\pi \right) \\ z &= 3 + i \left( -\frac{\pi}{2} + 2n\pi \right) \end{aligned}$$

**17.6.39**

$$\begin{aligned} \ln(-i) &= i \left( -\frac{\pi}{2} + 2n\pi \right) \\ (-i)^{4i} &= e^{4i \ln(-i)} \\ &= e^{4i \times i(-\pi/2 + 2n\pi)} \\ &= e^{2\pi(1-4n)} \end{aligned}$$

**17.6.41**

$$\begin{aligned} \ln(1+i) &= \log_e \sqrt{2} + i \left( \frac{\pi}{4} + 2n\pi \right) \\ (1+i)^{(1+i)} &= e^{(1+i) \ln(1+i)} \\ &= e^{(1+i)[\log_e \sqrt{2} + i(\pi/4 + 2n\pi)]} \\ &= e^{\log_e \sqrt{2} + i(\pi/4 + 2n\pi) + i \log_e \sqrt{2} - (\pi/4 + 2n\pi)} \\ &= e^{(\log_e \sqrt{2} - \pi/4 - 2n\pi) + i(\log_e \sqrt{2} + \pi/4 + 2n\pi)} \\ &= e^{-2n\pi} e^{(\log_e \sqrt{2} - \pi/4) + i(\log_e \sqrt{2} + \pi/4)} \\ &= e^{-2n\pi} e^{\log_e \sqrt{2} - \pi/4} e^{i(\log_e \sqrt{2} + \pi/4)} \\ &= e^{-2n\pi} (0.2739 + 0.5837i) \end{aligned}$$

**17.6.43**

$$\begin{aligned} \operatorname{Ln}(-1) &= \pi i \\ (-1)^{(-2i/\pi)} &= e^{(-2i/\pi) \operatorname{Ln}(-1)} \\ &= e^{(-2i/\pi)(\pi i)} \\ &= e^2 \end{aligned}$$

**17.6.47**

(a)

$$\begin{aligned}
(-1+i)^2 &= -2i \\
\operatorname{Ln}(-1+i)^2 &= \operatorname{Ln}(-2i) \\
&= \log_e 2 - \frac{\pi}{2}i \\
2\operatorname{Ln}(-1+i) &= 2\log_e \sqrt{2} + \frac{3\pi}{2}i \\
&\neq \operatorname{Ln}(-1+i)^2
\end{aligned}$$

Not true

(b)

$$\begin{aligned}
\operatorname{Ln} i^3 &= \operatorname{Ln}(-i) \\
&= -\frac{\pi}{2}i \\
3\operatorname{Ln} i &= \frac{3\pi}{2}i \\
&\neq \operatorname{Ln} i^3
\end{aligned}$$

Not true

(c)

$$\begin{aligned}
\ln i^3 &= i\left(-\frac{\pi}{2} + 2n\pi\right) \\
3\ln i &= 3i\left(\frac{\pi}{2} + 2n\pi\right) \\
&\neq \ln i^3
\end{aligned}$$

Not true

**17.7 Trigonometric and Hyperbolic Functions****17.7.1**

$$\begin{aligned}
\cos(3i) &= \cos 0 \cosh 3 - i \sin 0 \sinh 3 \\
&= \cosh 3 \\
&= 10.0677
\end{aligned}$$

**17.7.3**

$$\begin{aligned}
\sin(\pi/4 + i) &= \sin \frac{\pi}{4} \cosh 1 + i \cos \frac{\pi}{4} \sinh 1 \\
&= 1.0911 + 0.8309i
\end{aligned}$$

**17.7.5**

$$\begin{aligned}
\tan i &= \frac{\sin i}{\cos i} \\
&= \frac{\sin 0 \cosh 1 + i \cos 0 \sinh 1}{\cos 0 \cosh 1 + i \sin 0 \sinh 1} \\
&= \frac{i \sinh 1}{\cosh 1} \\
&= i \tanh 1 \\
&= 0.7615i
\end{aligned}$$

**17.7.7**

$$\begin{aligned}
\sec(\pi + i) &= \frac{1}{\cos(\pi + i)} \\
&= \frac{1}{\cos \pi \cosh 1 + \sin \pi \sinh 1} \\
&= -\frac{1}{\cosh 1} \\
&= -0.6480
\end{aligned}$$

**17.7.9**

$$\begin{aligned}
\cosh(\pi i) &= \cosh 0 \cos \pi + i \sinh 0 \sin \pi \\
&= -1
\end{aligned}$$

**17.7.11**

$$\begin{aligned}
\sinh(1 + \pi i/3) &= \sinh 1 \cos(\pi/3) + i \cosh 1 \sin(\pi/3) \\
&= 0.5876 + 1.3363i
\end{aligned}$$

17.7.15

$$\begin{aligned}
 \sin z &= 2 \\
 \frac{e^{iz} - e^{-iz}}{2i} &= 2 \\
 e^{iz} - e^{-iz} &= 4i \\
 e^{2iz} - 1 &= 4ie^{iz} \\
 e^{2iz} - 4ie^{iz} - 1 &= 0 \\
 e^{iz} &= \frac{4i \pm \sqrt{-16 + 4}}{2} \\
 &= (2 \pm \sqrt{3})i \\
 iz &= \log_e(2 \pm \sqrt{3}) + i(\pi/2 + 2n\pi) \\
 z &= (\pi/2 + 2n\pi) - i \log_e(2 \pm \sqrt{3})
 \end{aligned}$$

17.7.17

$$\begin{aligned}
 \sinh z &= -i \\
 \frac{e^z - e^{-z}}{2} &= -i \\
 e^{2z} + 2ie^z - 1 &= 0 \\
 e^z &= \frac{-2i \pm \sqrt{-4 + 4}}{2} \\
 &= -i \\
 z &= \ln(-i) \\
 &= i\left(-\frac{\pi}{2} + 2n\pi\right)
 \end{aligned}$$



17.7.19

$$\begin{aligned}
 \cos z &= \sin z \\
 \frac{e^{iz} + e^{-iz}}{2} &= \frac{e^{iz} - e^{-iz}}{2i} \\
 e^{iz} + e^{-iz} &= \frac{e^{iz} - e^{-iz}}{i} \\
 &= -i(e^{iz} - e^{-iz}) \\
 e^{2iz} + 1 &= -i(e^{2iz} - 1) \\
 e^{2iz}(1 + i) &= -1 + i \\
 e^{2iz} &= \frac{-1 + i}{1 + i} \\
 &= \frac{(-1 + i)(1 - i)}{(1 + i)(1 - i)} \\
 &= \frac{-1 + i + i + 1}{1 - i + i + 1} \\
 &= \frac{2i}{2} \\
 &= i \\
 2iz &= \ln i \\
 &= i \left( \frac{\pi}{2} + 2n\pi \right) \\
 z &= \frac{\pi}{4} + n\pi
 \end{aligned}$$

17.7.21

$$\begin{aligned}
 \cos z &= \cosh 2 \\
 \cos x \cosh y - i \sin x \sinh y &= \cosh 2 \\
 y &= \pm 2 \\
 x &= 2n\pi \\
 z &= 2n\pi \pm 2i
 \end{aligned}$$

## 17.8 Inverse Trigonometric and Hyperbolic Functions

### 17.8.1

$$\begin{aligned}\arcsin z &= -i \ln[iz + (1 - z^2)^{1/2}] \\ \arcsin(-i) &= -i \ln[i(-i) + (1 - (-i)^2)^{1/2}] \\ &= -i \ln[1 \pm \sqrt{2}] \\ \ln(1 + \sqrt{2}) &= \log_e(1 + \sqrt{2}) + 2n\pi i \\ \ln(1 - \sqrt{2}) &= \ln\left(-\frac{1}{1 + \sqrt{2}}\right) \\ &= -\ln[-(1 + \sqrt{2})] \\ &= -[\log_e(1 + \sqrt{2}) + i(\pi + 2n\pi)] \\ &= -\log_e(1 + \sqrt{2}) + i(\pi + 2n\pi) \\ \ln(1 \pm \sqrt{2}) &= (-1)^n \log_e(1 + \sqrt{2}) + n\pi i \\ \arcsin(-i) &= -i[(-1)^n \log_e(1 + \sqrt{2}) + n\pi i] \\ &= n\pi - (-1)^n i \log_e(1 + \sqrt{2}) \\ &= n\pi + (-1)^{n+1} i \log_e(1 + \sqrt{2})\end{aligned}$$

### 17.8.3

$$\begin{aligned}\arcsin 0 &= -i \ln(\pm 1) \\ &= -i(n\pi i) \\ &= n\pi\end{aligned}$$

### 17.8.5

$$\begin{aligned}\arccos 2 &= -i \ln[2 + i(1 - 2^2)^{1/2}] \\ &= -i \ln[2 \pm \sqrt{3}] \\ \ln(2 + \sqrt{3}) &= \log_e(2 + \sqrt{3}) + 2n\pi i \\ \ln(2 - \sqrt{3}) &= \log_e(2 - \sqrt{3}) + 2n\pi i \\ &= -\log_e(2 + \sqrt{3}) + 2n\pi i \\ \ln(2 \pm \sqrt{3}) &= \pm \log_e(2 + \sqrt{3}) + 2n\pi i \\ \arccos 2 &= 2n\pi \pm i \log_e(2 + \sqrt{3})\end{aligned}$$

**17.8.7**

$$\begin{aligned}\arccos \frac{1}{2} &= -i \ln \left\{ \frac{1}{2} + i \left[ 1 - \left( \frac{1}{2} \right)^2 \right]^{1/2} \right\} \\ &= -i \ln \left( \frac{1}{2} \pm \frac{\sqrt{3}}{2} i \right) \\ \ln \left( \frac{1}{2} \pm \frac{\sqrt{3}}{2} i \right) &= i \left( \pm \frac{\pi}{3} + 2n\pi \right) \\ \arccos \frac{1}{2} &= \pm \frac{\pi}{3} + 2n\pi\end{aligned}$$

**17.8.9**

$$\begin{aligned}\arctan 1 &= \frac{i}{2} \ln \frac{1+i}{-1+i} \\ \frac{1+i}{-1+i} &= \frac{(1+i)(-1-i)}{(-1+i)(-1-i)} \\ &= -i \\ \ln(-i) &= i \left( -\frac{\pi}{2} + 2n\pi \right) \\ \arctan 1 &= \frac{\pi}{4} + n\pi\end{aligned}$$

17.8.11

$$\begin{aligned}
 \operatorname{arcsinh} \frac{4}{3} &= \ln \left\{ \frac{4}{3} + \left[ \left( \frac{4}{3} \right)^2 + 1 \right]^{1/2} \right\} \\
 &= \ln \left( \frac{4}{3} \pm \frac{5}{3} \right) \\
 \ln \left( \frac{4}{3} + \frac{5}{3} \right) &= \ln \frac{9}{3} \\
 &= \ln 3 \\
 &= \log_e 3 + 2n\pi i \\
 \ln \left( \frac{4}{3} - \frac{5}{3} \right) &= \ln \left( -\frac{1}{3} \right) \\
 &= \log_e \frac{1}{3} + i(\pi + 2n\pi) \\
 &= -\log_e 3 + i(\pi + 2n\pi) \\
 \operatorname{arcsinh} \frac{4}{3} &= (-1)^n \log_e 3 + n\pi i
 \end{aligned}$$