Problem 13

In each of Problems 7 through 16, find the general solution of the given differential equation.

$$y'' + 2y' + 1.25y = 0$$

Solution

Since this is a linear homogeneous constant-coefficient ODE, the solution is of the form $y = e^{rt}$.

$$y = e^{rt} \quad \rightarrow \quad y' = re^{rt} \quad \rightarrow \quad y'' = r^2 e^{rt}$$

Substitute these expressions into the ODE.

$$r^2 e^{rt} + 2(re^{rt}) + 1.25(e^{rt}) = 0$$

Divide both sides by e^{rt}.

$$r^2 + 2r + 1.25 = 0$$

$$r = \frac{-2 \pm \sqrt{4 - 4(1.25)(1)}}{2} = \frac{-2 \pm \sqrt{-1}}{2} = \frac{-2 \pm i}{2} = -1 \pm \frac{i}{2}$$

$$r = \left\{-1 - \frac{i}{2}, -1 + \frac{i}{2}\right\}$$

Two solutions to the ODE are $y = e^{(-1-i/2)t}$ and $y = e^{(-1+i/2)t}$, so the general solution is a linear combination of the two.

$$\begin{aligned}
y(t) &= C_1 e^{(-1-i/2)t} + C_2 e^{(-1+i/2)t} \\
&= C_1 e^{-t-it/2} + C_2 e^{-t+it/2} \\
&= C_1 e^{-t} e^{-it/2} + C_2 e^{-t} e^{it/2} \\
&= C_1 e^{-t} \left[\cos\left(-\frac{t}{2}\right) + i \sin\left(-\frac{t}{2}\right)\right] + C_2 e^{-t} \left[\cos\left(\frac{t}{2}\right) + i \sin\left(\frac{t}{2}\right)\right] \\
&= C_1 e^{-t} \left(\cos\frac{t}{2} - i \sin\frac{t}{2}\right) + C_2 e^{-t} \left(\cos\frac{t}{2} + i \sin\frac{t}{2}\right) \\
&= C_1 e^{-t} \cos\frac{t}{2} - iC_1 e^{-t} \sin\frac{t}{2} + C_2 e^{-t} \cos\frac{t}{2} + iC_2 e^{-t} \sin\frac{t}{2} \\
&= (C_1 + C_2) e^{-t} \cos\frac{t}{2} + (-iC_1 + iC_2) e^{-t} \sin\frac{t}{2}
\end{aligned}$$

Therefore, using C_3 for $C_1 + C_2$ and C_4 for $-iC_1 + iC_2$, the real general solution is

$$y(t) = C_3 e^{-t} \cos\frac{t}{2} + C_4 e^{-t} \sin\frac{t}{2}.$$