

# Esercizi presi dall'eserciziario su moodle

## Equazioni differenziali di primo grado

▣ **Esercizio 1.1.1.** Si determini la soluzione  $y(t)$  del seguente problema di Cauchy

$$\begin{cases} y' = \frac{y^2}{y^2 + 4} t \\ y(0) = 2 \end{cases}$$

Inoltre si determini il valore  $\alpha > 0$  per cui  $\frac{y(t)}{t^\alpha}$  tende a un numero finito e non nullo per  $t \rightarrow +\infty$ .

$$\frac{y^2 + 4}{y^2} \cdot y' = t$$

$$\int \frac{y^2 + 4}{y^2} \cdot y' dt = \int t dt + C$$

$$\begin{aligned} u &= y \\ du &= y' dt \\ \downarrow u &= y \end{aligned}$$

$$\int \frac{y^2 + 4}{y^2} dy = \frac{t^2}{2} + C$$

$$\int 1 dy + 4 \int y^{-2} dy = \frac{t^2}{2} + C$$

$$y - \frac{4}{y} = \frac{t^2}{2} + C$$

$$\frac{y^2 - 4}{y} = \frac{t^2}{2} + C$$

$$y(0) = 2$$

$\downarrow$

$$\frac{2^2 - 4}{2} = \frac{0}{2} + C$$

$$\frac{0}{2} = C$$

$$C = 0 \rightarrow$$

$$\frac{y^2 - 4}{y} = \frac{t^2}{2} \rightarrow$$

$$\frac{y^2 - 4 - \frac{t^2 y}{2}}{y} = 0$$

$$y(t) = \frac{\frac{t^2}{2} \pm \sqrt{\frac{t^4}{4} + 16}}{2} = \frac{t^2 \pm \sqrt{t^4 + 64}}{4}$$

$$\downarrow$$

$$y(0) = 2$$

$$\downarrow$$

$$\frac{0^2 \pm \sqrt{64}}{4} = \begin{cases} +2 \\ -2 \end{cases} \quad (\text{Non accettabile}) \rightarrow y(0) = 2$$

Soluzione 1:

$$y(t) = \frac{t^2 + \sqrt{t^4 + 64}}{4}$$

$$\lim_{t \rightarrow +\infty} \frac{y(t)}{t^\alpha} = \frac{t^2 + \sqrt{t^4 + 64}}{4 t^\alpha} = \lim_{t \rightarrow +\infty} \frac{t^2 + t^2 \sqrt{1 + \frac{64}{t^4}}}{4 t^\alpha} =$$

$$= \lim_{t \rightarrow +\infty} \frac{x t^2}{4 t^\alpha} = \lim_{t \rightarrow +\infty} \frac{t^2}{2 t^\alpha}$$

$1 + \frac{64}{+\infty} = 1$

L'unico modo per avere un numero finito è che il grado del numeratore e del denominatore sia uguale, quindi:

$$\alpha = 2 \rightarrow \lim_{t \rightarrow +\infty} \frac{t^2}{2 t^2} = \lim_{t \rightarrow +\infty} \frac{1}{2} = \frac{1}{2}$$

▣ **Esercizio 1.1.2.** Si determini la soluzione  $y(t)$  del seguente problema di Cauchy

$$\begin{cases} y' = \frac{t^2 + t}{2e^{2y} + 6e^y} \\ y(0) = 0 \end{cases}$$

$$y' \cdot (2e^{2y} + 6e^y) = t^2 + t$$

$$\int y' \cdot (2e^{2y} + 6e^y) dt = \int t^2 + t dt + C$$

$$u = y$$

$$\downarrow u = y' dt$$

$$\downarrow u = y$$

$$2 \int e^{2y} dy + 6 \int e^y dy = \frac{t^3}{3} + \frac{t^2}{2} + C$$

$$\nearrow \frac{e^{2y}}{2} + 6 e^y = \frac{t^3}{3} + \frac{t^2}{2} + C$$

$$y(0) = 0$$

$$e^{2 \cdot 0} + 6 e^0 = \frac{0}{3} + \frac{0}{2} + C$$

$$1 + 6 = C$$

$$C = 7$$

↓

$$e^{2y} + 6 e^y = \frac{t^3}{3} + \frac{t^2}{2} + 7$$

$$x = e^y \rightarrow y = \ln(x)$$

$$x^2 + 6x - \frac{t^3}{3} - \frac{t^2}{2} - 7 = 0$$

$$x_{1,2} = \frac{-\frac{b}{2} \pm \sqrt{\frac{b^2}{4} - ac}}{a} = -3 \pm \sqrt{\frac{t^3}{3} + \frac{t^2}{2} + 16}$$

$$e^y = -3 \pm \sqrt{\frac{t^3}{3} + \frac{t^2}{2} + 16}$$

$$y(0) = 0$$

$$e^0 = -3 \pm \sqrt{\frac{0}{3} + \frac{0}{2} + 16} = -3 \pm \sqrt{16} = -3 \pm 4 = \begin{cases} -7 & \text{Non accettabile} \\ 1 \end{cases}$$

$$y(t) = \ln \left( -3 + \sqrt{\frac{t^3}{3} + \frac{t^2}{2} + 16} \right)$$

↓

$$y(0) = \ln(1) = 0 \quad \checkmark$$

✎ Esercizio 1.1.4. Sia  $y(t)$  la soluzione del problema di Cauchy

$$\begin{cases} y' = \frac{e^{-x}\sqrt{y+1}}{e^{-x}+1} \\ y(0) = 1 \end{cases}$$

$$y' = \frac{e^{-x}\sqrt{y+1}}{e^{-x}+1}$$

$$\frac{y'}{\sqrt{y+1}} = \frac{e^{-x}}{e^{-x}+1}$$

$$\int \frac{y'}{\sqrt{y+1}} dy = \int \frac{e^{-x}}{e^{-x}+1} dx$$

$$y = v$$

$$- \int (y+1)^{-\frac{1}{2}} dy = \int \frac{-e^{-x}}{e^{-x}+1} dx$$

$$y' dy = dv$$

$$\leftarrow v = y$$

$$C + \frac{-(y+1)^{\frac{1}{2}}}{\frac{1}{2}} = \int \frac{F'}{F} dF$$

$$\leftarrow \begin{cases} e^{-x}+1 = F \\ F' = -e^{-x} \end{cases}$$

$$-2\sqrt{y+1} = \int \frac{dF}{F}$$

$$-2\sqrt{y+1} = \ln(F) + C$$

$$\sqrt{y+1} = -\frac{1}{2} \ln(e^{-x}+1) + C$$

$$y = \left( -\frac{1}{2} \ln(e^{-x}+1) + C \right)^2 - 1$$

$$y(0) = 1$$

↓

$$1 = \left( -\frac{1}{2} \ln(2) + C \right)^2 - 1$$

$$2 = \left( -\frac{1}{2} \ln(2) + C \right)^2$$

$$\sqrt{z} = -\frac{1}{2} \ln(z) + c$$

$$c = \sqrt{z} + \frac{1}{2} \ln(z)$$

$$y = \left( -\frac{1}{2} \ln(e^{-x} + 1) + \sqrt{z} + \frac{1}{2} \ln(z) \right)^2 - 1$$

▮ **Esercizio 1.1.5.** Si determini la soluzione  $y(t)$  del seguente problema di Cauchy

$$\begin{cases} y' = (e^{-3y} + 1)(2x - 1) \\ y(0) = -1 \end{cases}$$

$$y' = (e^{-3y} + 1)(2x - 1)$$

$$\frac{y'}{e^{-3y} + 1} = 2x - 1$$

$$\int \frac{y'}{e^{-3y} + 1} dy = \int (2x - 1) dx$$

$$\int \frac{1}{e^{-3y} + 1} dy = 2 \int x dx - \int 1 dx$$

$$\int \frac{1}{e^{-3y} + 1} dy = x^2 - x + C$$

$$\int \frac{1}{e^{-3y} \left(1 + \frac{1}{e^{-3y}}\right)} dy = x^2 - x + C$$

$$\int \frac{e^{3y}}{1 + e^{3y}} dy = x^2 - x + C$$

$$\frac{d(1 + e^{3y})}{dy} = 3e^{3y}$$

$$3 \int \frac{e^{3y}}{1 + e^{3y}} dy = 3(x^2 - x + C)$$



$$c = \ln(e^{-3} + 1)$$

$$y = \frac{\ln(e^{3x^2-3x} \cdot e^{\ln(e^{-3}+1)} - 1)}{3}$$

$$y = \frac{\ln((1+e^{-3})e^{3x^2-3x} - 1)}{3}$$

$$y = \frac{1}{3} \ln((1+e^{-3})e^{3x^2-3x} - 1)$$

✎ **Esercizio 1.1.6.** Si determini la soluzione  $y(t)$  del seguente problema di Cauchy

$$\begin{cases} y' = (3 + 27y^2)(xe^{3x} - 2x^2) \\ y(0) = 0 \end{cases}$$

$$y' = (3 + 27y^2)(xe^{3x} - 2x^2)$$

$$\int \frac{y'}{3 + 27y^2} dy = \int (xe^{3x} - 2x^2) dx$$

$$\int \frac{1}{3 + 27y^2} dy = \int xe^{3x} dx - 2 \int x^2 dx$$

$$\frac{1}{3} \int \frac{1}{1 + 9y^2} dy = \underbrace{\int xe^{3x} dx}_{\downarrow} - 2 \frac{x^3}{3} + C$$

$$\int f(x) g'(x) dx = f(x) g(x) - \int f'(x) g(x) dx$$

$$F: x \quad F': 1$$

$$g': e^{3x} \quad g: \frac{1}{3} e^{3x}$$

$$\frac{1}{3} \int \frac{1}{1 + 9y^2} dy = \frac{1}{3} x e^{3x} - \frac{1}{3} \int e^{3x} dx - 2 \frac{x^3}{3} + C$$

$$\frac{1}{3} \int \frac{1}{1+9y^2} dy = \frac{1}{3} x e^{3x} - \frac{1}{9} e^{3x} - 2 \frac{x^3}{3} + C$$

$$\int \frac{1}{1+9y^2} dy = x e^{3x} - \frac{1}{3} e^{3x} - 2x^3 + C$$

↓

$$\frac{1}{x^2+a^2} = \frac{1}{a} \arctan\left(\frac{x}{a}\right)$$

↓

$$\frac{1}{9} \int \frac{1}{y^2 + \frac{1}{9}} dy = x e^{3x} - \frac{1}{3} e^{3x} - 2x^3 + C$$

$$\frac{1}{3} \arctan(3y) = x e^{3x} - \frac{1}{3} e^{3x} - 2x^3 + C$$

$$\arctan(3y) = 3x e^{3x} - e^{3x} - 6x^3 + C$$

$$\arctan(x) = a$$

↓

$$x = \tan(a)$$

$$3y = \tan(3x e^{3x} - e^{3x} - 6x^3 + C)$$

$$y = \frac{1}{3} \tan(3x e^{3x} - e^{3x} - 6x^3 + C)$$

$$\tan(a) = 0$$

$$y(0) = 0$$

↓

$$a = \arctan(0)$$

$$0 = \frac{1}{3} \tan(0 - 1 - 0 + C)$$

$$\tan(-1 + C) = 0$$

$$-1 + C = \arctan(0)$$

$$C = 1$$

$$y = \frac{1}{3} \tan(3x e^{3x} - e^{3x} - 6x^3 + 1)$$



## Equazioni differenziali: lineari di secondo grado

▢ **Esercizio 1.2.1.** Si determini la soluzione  $y(t)$  del seguente problema di Cauchy

$$\begin{cases} y'' - 6y' + 9y = 3t + 2 \\ y(0) = -1 \\ y'(0) = 2 \end{cases}$$

$3t + 2$  è un polinomio di grado 1

$$q_1 = a_0 + a_1 x$$

Sostituisco  $\rightarrow$

$$-6a_1 + 9a_0 + 9a_1 x = 3x + 2$$

$$q_1' = a_1$$

$$-6a_1 + 9a_0 + 9a_1 x = 3x + 2$$

$$q_1'' = 0$$

$$\begin{cases} -6a_1 + 9a_0 = 2 \\ 9a_1 = 3 \end{cases}$$

$$\begin{cases} -2 + 9a_0 = 2 \\ a_1 = \frac{1}{3} \end{cases}$$

$$\begin{cases} a_0 = \frac{4}{9} \\ a_1 = \frac{1}{3} \end{cases}$$

$$\rightarrow y_1 = \frac{4}{9} + \frac{1}{3}t$$

Risolve l'equazione omogenea

$$r'' - 6r' + 9r = 0$$

$$(r-3)^2$$

$$r_{1,2} = 3 \rightarrow y_2 = C_1 e^{3t} + C_2 t e^{3t}$$

$$y(t) = \frac{4}{9} + \frac{1}{3}t + C_1 e^{3t} + C_2 t e^{3t}$$

Applico le condizioni di Cauchy

$$y(0) = \frac{4}{9} + 0 + C_1 + 0 = \frac{4}{9} + C_1 = -1 \rightarrow C_1 = -\frac{13}{9}$$

$$y'(t) = \frac{1}{3} + 3C_1 e^{3t} + C_2 e^{3t} + 3C_2 t e^{3t}$$

$$y'(0) = \frac{1}{3} + 3C_1 + C_2 = 2 \rightarrow \frac{1}{3} + 3 \cdot \left(-\frac{13}{9}\right) + C_2 = 2$$

$$\frac{1}{3} - \frac{13}{3} + C_2 = 2$$

$$1 - 13 + 3C_2 = 6$$

$$3C_2 = 6 + 12$$

$$C_2 = \frac{18}{3} = 6$$

$$C_1 = -\frac{13}{9} \quad C_2 = 6$$

↓

$$y(t) = \frac{4}{9} + \frac{1}{3}t + C_1 e^{3t} + C_2 t e^{3t} = \frac{4}{9} + \frac{1}{3}t - \frac{13}{9} e^{3t} + 6 t e^{3t}$$

▣ **Esercizio 1.2.2.** Sia  $y(t)$  la soluzione del problema di Cauchy

$$\begin{cases} y'' + 2y' - 3y = 0 \\ y(0) = 0 \\ y'(0) = 1. \end{cases}$$

Allora  $\lim_{t \rightarrow +\infty} y(t) =$

- ☐ 0;
- ☐ non esiste;
- ☐  $+\infty$ ;
- ☐  $-\infty$

Risolvero l'equazione caratteristica

$$r^2 + 2r - 3 = 0$$

$$(r+3)(r-1)$$

$$r_1 = -3 \quad r_2 = 1$$

$$y(t) = C_1 e^{-3t} + C_2 e^t$$

$$y'(t) = -3C_1 e^{-3t} + C_2 e^t$$

Impongo le condizioni di Cauchy

$$\begin{cases} y(0) = C_1 + C_2 = 0 \\ y'(0) = -3C_1 + C_2 = 1 \end{cases} \rightarrow \begin{cases} C_1 = -C_2 \\ 3C_2 + C_2 = 1 \end{cases} \rightarrow \begin{cases} C_1 = -\frac{1}{4} \\ C_2 = \frac{1}{4} \end{cases}$$

$$y(t) = -\frac{1}{4}e^{-3t} + \frac{1}{4}e^t$$

$$\lim_{t \rightarrow +\infty} y(t) = -\frac{1}{4}e^{-\infty} + \frac{1}{4}e^{\infty} = 0 + \infty = +\infty$$

La risposta corretta è la terza

✎ **Esercizio 1.2.3.** Si determini la soluzione  $y(t)$  del problema di Cauchy

$$\begin{cases} y'' - y' - 2y = \cos(2t) \\ y(0) = 1 \\ y'(0) = 0. \end{cases}$$

Risolvero l'equazione omogenea associata

$$r^2 - r - 2 = 0$$

$$(r-2)(r+1)$$

$$r_1 = -1 \quad r_2 = 2 \rightarrow z(t) = c_1 e^{-t} + c_2 e^{2t}$$

Con il metodo di somiglianza cerco una soluzione particolare dell'equazione non omogenea:

$$\bar{y}(t) = \alpha \sin(2t) + \beta \cos(2t)$$

$$\bar{y}'(t) = 2\alpha \cos(2t) - 2\beta \sin(2t)$$

$$\bar{y}''(t) = -4\alpha \sin(2t) - 4\beta \cos(2t)$$

$$y'' - y' - 2y = \cos(2t)$$

↓

$$-4\alpha \sin(2t) - 4\beta \cos(2t) - 2\alpha \cos(2t) + 2\beta \sin(2t) - 2\alpha \sin(2t) - 2\beta \cos(2t) = \cos(2t)$$

$$\sin(2t)(-4\alpha + 2\beta - 2\alpha) + \cos(2t)(-4\beta - 2\alpha - 2\beta) = \cos(2t)$$

$$\sin(2t)(-6\alpha + 2\beta) + \cos(2t)(-6\beta - 2\alpha) = \cos(2t)$$

$$\begin{cases} -6\alpha + 2\beta = 0 \\ -6\beta - 2\alpha = 1 \end{cases} \quad \begin{cases} \beta = 3\alpha \\ -18\alpha - 2\alpha = 1 \end{cases} \quad \begin{cases} \beta = -\frac{3}{20} \\ \alpha = -\frac{1}{20} \end{cases}$$

$$\bar{y}(t) = -\frac{1}{20} \sin(2t) - \frac{3}{20} \cos(2t)$$

$$y(t) = z(t) + \bar{y}(t) = C_1 e^{-t} + C_2 e^{2t} - \frac{1}{20} \sin(2t) - \frac{3}{20} \cos(2t)$$

$$y'(t) = -C_1 e^{-t} + 2C_2 e^{2t} - \frac{1}{10} \cos(2t) + \frac{3}{10} \sin(2t)$$

Applico le condizioni di Cauchy

$$\begin{cases} y(0) = C_1 + C_2 - \frac{3}{20} = 1 \\ y'(0) = -C_1 + 2C_2 - \frac{1}{10} = 0 \end{cases} \rightarrow \begin{cases} C_1 = -C_2 + \frac{23}{20} \\ -C_1 + 2C_2 = \frac{1}{10} \end{cases} \begin{cases} C_1 = -C_2 + \frac{23}{20} \\ C_2 - \frac{23}{20} + 2C_2 = \frac{1}{10} \end{cases}$$

$$\begin{cases} C_1 = -C_2 + \frac{23}{20} \\ 3C_2 = \frac{2}{20} + \frac{23}{20} \end{cases} \begin{cases} C_1 = -\frac{5}{12} + \frac{23}{20} \\ C_2 = \frac{5}{12} \end{cases} \begin{cases} C_1 = \frac{-25+69}{60} = \frac{44}{60} = \frac{11}{15} \\ C_2 = \frac{5}{12} \end{cases}$$

$$y(t) = \frac{11}{15} e^{-t} + \frac{5}{12} e^{2t} - \frac{1}{20} \sin(2t) - \frac{3}{20} \cos(2t)$$

▣ **Esercizio 1.2.4.** Si determini la soluzione  $y(t)$  del problema di Cauchy

$$\begin{cases} y'' - 4y' + 8y = e^{-2t} \\ y(0) = -1 \\ y'(0) = 0. \end{cases}$$

Risolvero l'equazione omogenea associata

$$r^2 - 4r + 8 = 0$$

$$r_{1,2} = \frac{4 \pm \sqrt{16 - 32}}{2} = \frac{4 \pm i\sqrt{16}}{2} = \frac{4 \pm 4i}{2} = 2 \pm 2i$$

$$r_1 = 2 - 2i \quad r_2 = 2 + 2i$$

$$z(t) = C_1 e^{2t} \sin(2t) + C_2 e^{2t} \cos(2t)$$

Bisogna trovare una soluzione particolare del tipo:

$$\bar{y}(t) = e^{-2t} \gamma(t) \quad \begin{matrix} A = 1 \\ \lambda = -2 \end{matrix}$$

↓

$$\gamma'' + \gamma'(2(-2) - 4) + \gamma(4 + 8 + 8) = 1$$

$$y'' - 3y' + 20y = 1$$

$$\lambda^2 + \lambda a + b \neq 0 \rightarrow y(t) = \cos t + a_1 t + e = \frac{A}{\lambda^2 + \lambda a + b} = \frac{1}{20}$$

$$\bar{y}(t) = \frac{1}{20} e^{-2t}$$

$$y(t) = z(t) + \bar{y}(t) = c_1 e^{2t} \sin(2t) + c_2 e^{2t} \cos(2t) + \frac{1}{20} e^{-2t}$$

$$y'(t) = 2c_1 e^{2t} \sin(2t) + 2c_1 e^{2t} \cos(2t) + 2c_2 e^{2t} \cos(2t) - 2c_2 e^{2t} \sin(2t) - \frac{1}{10} e^{-2t}$$

$$\begin{cases} y(0) = c_2 + \frac{1}{20} = -1 \\ y'(0) = 2c_1 + 2c_2 - \frac{1}{10} = 0 \end{cases} \rightarrow \begin{cases} c_2 = -\frac{21}{20} \\ c_1 = \frac{11}{10} \end{cases}$$

$$y(t) = \frac{11}{10} e^{2t} \sin(2t) - \frac{21}{20} e^{2t} \cos(2t) + \frac{1}{20} e^{-2t}$$

✎ **Esercizio 1.2.5.** Si determini la soluzione  $y(t)$  del problema di Cauchy

$$\begin{cases} y'' - y' - 2y = \sin(2t) \\ y(0) = 0 \\ y'(0) = 1. \end{cases}$$

Risolvo l'equazione omogenea associata

$$r^2 - r - 2 = 0$$

$$(r-2)(r+1)$$

$$r_1 = -1 \quad r_2 = 2$$

$$z(t) = c_1 e^{-t} + c_2 e^{2t}$$

Bisogna trovare una soluzione particolare del tipo:

$$\bar{y}(t) = \alpha \sin(2t) + \beta \cos(2t)$$

$$\bar{y}'(t) = 2\alpha \cos(2t) - 2\beta \sin(2t)$$

$$\bar{y}''(t) = -4\alpha \sin(2t) - 4\beta \cos(2t)$$

$$y'' - y' - 2y = \sin(2t)$$

↓

$$-4\alpha \sin(2t) - 4\beta \cos(2t) - 2\alpha \cos(2t) + 2\beta \sin(2t) - 2\alpha \sin(2t) - 2\beta \cos(2t) = \sin(2t)$$

$$\sin(2t) (-4\alpha + 2\beta - 2\alpha) + \cos(2t) (-4\beta - 2\alpha - 2\beta) = \sin(2t)$$

$$\sin(2t) (-6\alpha + 2\beta) + \cos(2t) (-6\beta - 2\alpha) = \sin(2t)$$

$$\begin{cases} -6\alpha + 2\beta = 1 \\ -6\beta - 2\alpha = 0 \end{cases} \quad \begin{cases} -6\alpha - \frac{2}{3}\alpha = 1 \\ \beta = -\frac{1}{3}\alpha \end{cases} \quad \begin{cases} -\frac{20}{3}\alpha = 1 \\ \beta = -\frac{1}{3}\alpha \end{cases} \quad \begin{cases} \alpha = -\frac{3}{20} \\ \beta = +\frac{1}{20} \end{cases}$$

$$\overline{y}(t) = -\frac{3}{20}\sin(2t) + \frac{1}{20}\cos(2t)$$

$$y(t) = c_1 e^{-t} + c_2 e^{2t} - \frac{3}{20}\sin(2t) + \frac{1}{20}\cos(2t)$$

$$y'(t) = -c_1 e^{-t} + 2c_2 e^{2t} - \frac{3}{10}\cos(2t) - \frac{1}{10}\sin(2t)$$

Impongo le condizioni di Cauchy

$$\begin{cases} y(0) = c_1 + c_2 + \frac{1}{20} = 0 \\ y'(0) = -c_1 + 2c_2 - \frac{3}{10} = 1 \end{cases} \rightarrow \begin{cases} c_1 = -c_2 - \frac{1}{20} \\ c_2 + \frac{1}{20} + 2c_2 - \frac{3}{10} = 1 \end{cases} \quad \begin{cases} c_1 = -c_2 - \frac{1}{20} \\ 3c_2 - \frac{5}{20} = 1 \end{cases}$$

$$\begin{cases} c_1 = -\frac{25}{60} - \frac{1}{20} = \frac{-25-3}{60} = -\frac{28}{60} = -\frac{7}{15} \\ c_2 = \frac{25}{60} = \frac{5}{12} \end{cases}$$

$$y(t) = -\frac{7}{15} e^{-t} + \frac{5}{12} e^{2t} - \frac{3}{20}\sin(2t) + \frac{1}{20}\cos(2t)$$

✎ **Esercizio 1.2.6.** Determinate la soluzione generale dell'equazione differenziale  $y'' - 4y' + 13y = 4x$ .

Risolvo l'equazione omogenea associata

$$r^2 - 4r + 13 = 0$$

$$r_{1,2} = \frac{4 \pm \sqrt{16 - 52}}{2} = \frac{4 \pm i\sqrt{24}}{2} = \frac{4 \pm 4i\sqrt{3}}{2} = 2 \pm 2\sqrt{3}i$$

$$z(t) = C_1 e^{2t} \cos(2\sqrt{3}t) + C_2 e^{2t} \sin(2\sqrt{3}t)$$

✎ **Esercizio 1.2.7.** Determinare la soluzione generale dell'equazione differenziale

$$2y'' + 3y' + 4y = 0.$$

$$2r^2 + 3r + 4 = 0$$

$$r_{1,2} = \frac{-3 \pm \sqrt{9 - 32}}{4} = \frac{-3 \pm i\sqrt{23}}{4} = \frac{-3 \pm 4\sqrt{7}i}{4} = -\frac{3}{4} \pm \sqrt{7}i$$

$$y(t) = C_1 e^{-\frac{3}{4}t} \cos(\sqrt{7}t) + C_2 e^{-\frac{3}{4}t} \sin(\sqrt{7}t)$$

✎ **Esercizio 1.2.8.** Si risolva il seguente problema di Cauchy:

$$y'' + 6y' + 8y = e^{4t} + t^2, \quad y(1) = 2, \quad y'(1) = 3.$$

Risolvo l'equazione omogenea associata

$$r^2 + 6r + 8 = 0$$

$$(r+4)(r+2)$$

$$r_1 = -4 \quad r_2 = -2$$

$$z(t) = C_1 e^{-4t} + C_2 e^{-2t}$$

Bisogna trovare una soluzione particolare:

$$\bar{y}_\lambda(t) = e^{\lambda t} \gamma(t) \quad \lambda = 4 \quad A = 1$$

↓

$$\lambda^2 + \lambda a + b = 16 + 4 + 8 = 28 \neq 0 \rightarrow \gamma = \text{costante} = \frac{A}{\lambda^2 + \lambda a + b} = \frac{1}{28}$$

$$\bar{y}_1(t) = \frac{1}{26} e^{4t}$$

$$\bar{y}_2(t) = a_0 + a_1 x + a_2 x^2 = t^2$$

$$\bar{y}'_2(t) = a_1 + a_2 x$$

$$\bar{y}''_2(t) = a_2$$

Sostituisco

$$y'' + 6y' + 8y = t^2$$

$$a_2 + 6a_1 + 8a_2 x + 8a_0 + 8a_1 x + 8a_2 x^2 = t^2$$

$$a_2 + 6a_1 + 8a_0 + x(6a_2 + 8a_1) + 8a_2 x^2 = t^2$$

$$\begin{cases} a_2 + 6a_1 + 8a_0 = 0 \\ 6a_2 + 8a_1 = 0 \\ a_2 = \frac{1}{8} \end{cases} \quad \begin{cases} \frac{1}{8} - \frac{18}{32} + 8a_0 = 0 \\ a_1 = -\frac{3}{32} \\ a_2 = \frac{1}{8} \end{cases} \quad \begin{cases} a_0 = \frac{7}{128} \\ a_1 = -\frac{3}{32} \\ a_2 = \frac{1}{8} \end{cases}$$

$$\bar{y}_2(t) = \frac{7}{128} - \frac{3}{32} x + \frac{1}{8} x^2$$

$$\bar{y}(t) = \bar{y}_1 + \bar{y}_2 = \frac{1}{26} e^{4t} + \frac{7}{128} - \frac{3}{32} x + \frac{1}{8} x^2$$

**Esercizio 1.2.10.** Si determini la soluzione  $y(t)$  del problema di Cauchy

$$\begin{cases} y'' + y' - 2y = -e^x \\ y(0) = 0 \\ y'(0) = 0. \end{cases}$$

Risolviamo l'equazione omogenea associata

$$r^2 + r - 2 = 0$$

$$(r-1)(r+2)$$

$$r_1 = -2 \quad r_2 = 1$$

$$z(x) = c_1 e^{-2x} + c_2 e^x$$





