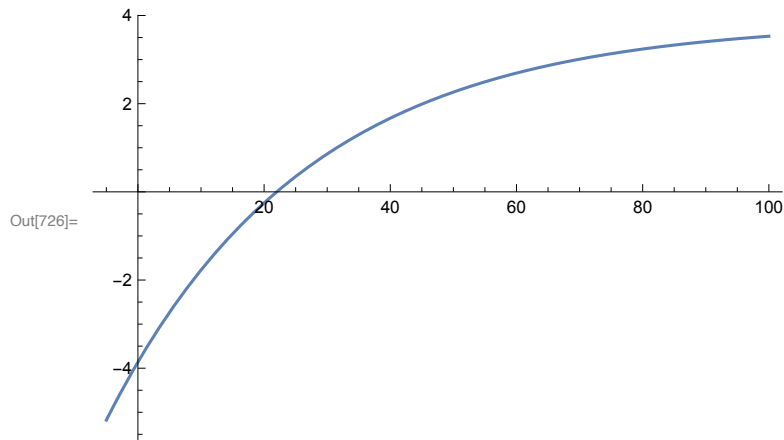# NMRI

```
In[719]:= Clear["Global`*"]
        Solve[Integrate[1 / (mo - mz), mz] == Integrate[1 / t1, t], mz];
        (*I get mz = cExp[-t/t1]+mo at t=0 mz = -mo → c = -2mo       note,
        mo is last recorded*)
        Clear["Global`*"]
        mz[t_] := mo (1 - 2 Exp[-t / t1]) + c
        t1 = 22 / Log[2] // N
        mo = 3.86;
        c = 0;
        Plot[mz[t], {t, -5, 100}]
```

Out[723]= 31.7393

Out[726]=

The first step is to import the data. I used excel while taking my data then exported it to .txt. My first column was the time and the second column was my measurement. Remove semi colons to see and manipulate data.

```
In[698]:=  Clear["Global`*"]
           data = {{0, -3.88`}, {1, -3.72`}, {2, -3.52`}, {3, -3.28`}, {4, -3.08`},
               {5, -2.84`}, {6, -2.64`}, {7, -2.44`}, {8, -2.28`}, {9, -2.08`},
               {10, -1.88`}, {11, -1.76`}, {12, -1.56`}, {13, -1.4`}, {14, -1.24`},
               {15, -1.02`}, {16, -0.872`}, {17, -0.688`}, {18, -0.504`}, {19, -0.298`},
               {20, -0.114`}, {21, -0.016`}, {22, 0.012`}, {23, 0.116`}, {24, 0.292`},
               {25, 0.464`}, {26, 0.6`}, {27, 0.732`}, {28, 0.864`}, {29, 0.976`},
               {30, 1.08`}, {31, 1.17`}, {32, 1.24`}, {33, 1.34`}, {34, 1.42`}, {35, 1.5`},
               {36, 1.58`}, {37, 1.66`}, {38, 1.72`}, {39, 1.8`}, {40, 1.88`}, {41, 1.96`},
               {42, 1.98`}, {43, 2.06`}, {44, 2.12`}, {45, 2.18`}, {46, 2.22`}, {47, 2.28`},
               {48, 2.34`}, {49, 2.38`}, {50, 2.42`}, {51, 2.48`}, {52, 2.56`}, {53, 2.58`},
               {54, 2.62`}, {55, 2.66`}, {56, 2.7`}, {57, 2.74`}, {58, 2.8`}, {59, 2.82`},
               {60, 2.88`}, {61, 2.9`}, {62, 2.92`}, {63, 2.98`}, {64, 3.02`}, {65, 3.04`},
               {66, 3.06`}, {67, 3.1`}, {68, 3.12`}, {69, 3.16`}, {70, 3.2`}, {71, 3.22`},
               {72, 3.26`}, {73, 3.26`}, {74, 3.3`}, {75, 3.34`}, {76, 3.36`}, {77, 3.4`},
               {78, 3.42`}, {79, 3.44`}, {80, 3.46`}, {81, 3.48`}, {82, 3.5`}, {83, 3.54`},
               {84, 3.54`}, {85, 3.56`}, {86, 3.6`}, {87, 3.62`}, {88, 3.64`}, {89, 3.66`},
               {90, 3.68`}, {91, 3.72`}, {92, 3.74`}, {93, 3.74`}, {94, 3.78`}, {95, 3.8`},
               {96, 3.8`}, {97, 3.82`}, {98, 3.82`}, {99, 3.84`}, {100, 3.86`}};

           (*data =
            ReadList["/Users/christophernewey/Desktop/data/nmri1.txt", {Number,Number}]*)

           function[t_] := m0 * (1 - 2 Exp[-t / t1]) + c;
           fit = NonlinearModelFit[data, function[t],
              {{m0, 1}, {c, 1}, {t1, 1}}, t, MaxIterations → Infinity]
           MatrixForm[fit["CovarianceMatrix"]]
           fit["ParameterTable"]
           t1 = t1 /. fit["BestFitParameters"]
           m0 = m0 /. fit["BestFitParameters"]
           c = c /. fit["BestFitParameters"]
```

Out[701]= FittedModel[$0.0458854 + 4.08734 \left(1 - 2 e^{-0.0316529 t}\right)$]

Out[702]//MatrixForm=

$$\begin{pmatrix} 0.00011965 & -0.0000339142 & 0.000191426 \\ -0.0000339142 & 0.000324762 & 0.00417233 \\ 0.000191426 & 0.00417233 & 0.0635088 \end{pmatrix}$$

Out[703]=

|	Estimate	Standard Error	t-Statistic	P-Value
m0	4.08734	0.0109385	373.666	2.27554×10^{-156}
c	0.0458854	0.0180212	2.5462	0.0124481
t1	31.5927	0.25201	125.363	5.29258×10^{-110}

Out[704]= 31.5927

Out[705]= 4.08734

Out[706]= 0.0458854

In[707]:=
```
p2 = Plot[fit["BestFit"], {t, -1, 100}, PlotStyle → Blue];
p1 = ListPlot[data, PlotRange → All,
    PlotStyle → Red, PlotLabel → "NMRI Relaxation Time", Frame → True,
    FrameLabel → {"Time Delay (ms)", "Relative Intensity (Volts)"},
    LabelStyle → {FontFamily → "Latin Modern Math", 16, GrayLevel[0]}];
label1 = "Raw Data";
label2 = StringForm["``+``(1-2Exp[-t/``])",
    NumberForm[c, {4, 2}], NumberForm[m0, {2, 1}], NumberForm[t1, {4, 2}]];
lg1 = PointLegend[{Red}, {label1}, LabelStyle →
     {FontFamily → "Latin Modern Math", 16, GrayLevel[0]}];
lg2 = LineLegend[{Blue}, {label2}, LegendMarkers → "",
    LabelStyle → {FontFamily → "Latin Modern Math", 16, GrayLevel[0]}];
Legended[
 Show[p1, p2, ImageSize → Large],
 (Placed[#, {Left, Top}] & /@ {lg1, lg2})]
```
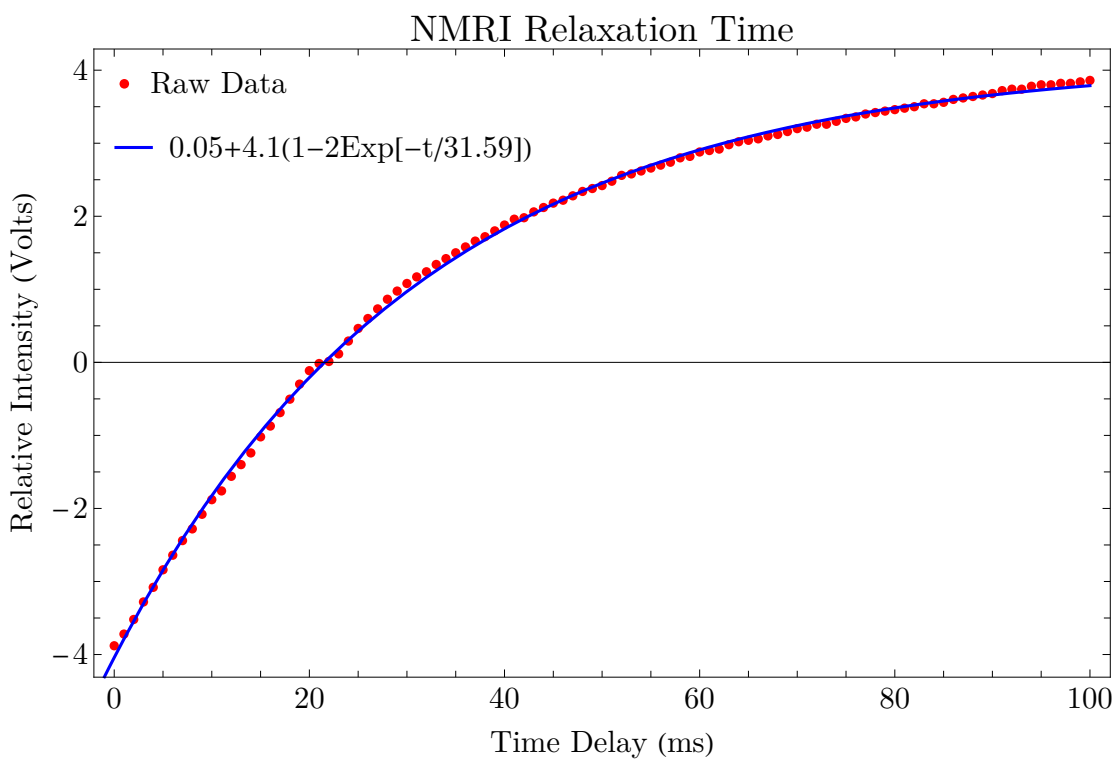
Out[713]=

Residual Plot

```
In[714]:= nlmfitresiduals =
    Table[{data[[i, 1]], data[[i, 2]] - fit[data[[i, 1]]]}, {i, 1, Length[data]}];
  Total[nlmfitresiduals[[All, 2]]]
  rsenlm = Sqrt[Total[nlmfitresiduals[[All, 2]]^2 / (Length[data] - 2)];


  lbres1 = StringTemplate["Nlm RSE = ``\nRSE = √( (∑_{i=1}^n (y_i - f (x_i))^2) / (n - 2) ) "][

    NumberForm[rsenlm, {3, 2}]];
  ListPlot[nlmfitresiduals,
   PlotRange → All,
   Filling → Axis,
   PlotStyle → {Red, Green, Blue},
   Frame → True,
   FrameLabel → {"Fitted Value", "Residuals"},
   PlotLabel → "Fit Residuals",
   PlotLegends → Placed[LineLegend[{lbres1},
     LegendFunction → (Framed[#, FrameMargins → 0, Background → Opacity[.7, White],
        FrameStyle → Directive[Black]] &)], {Right, Top}],
   LabelStyle → {20, GrayLevel[0], FontFamily → "Latin Modern Math"},
   ImageSize → Large]
```

Out[715]= -2.77556×10^{-14}

Out[718]=

Fit Residuals

$$RSE = \sqrt{\frac{\sum_{i=1}^{n}(y_i - f(x_i))^2}{(n-2)}}$$

Nlm RSE = 0.06