Question 1: Fit the following datasets to the following curves and obtain best fit parameters. Plot the data next to each curve fit.

- **Part A**: `curvefit_dataset1.csv` to axe^{-bx}.
- **Part B**: `curvefit_dataset2.csv` to $ae^{-b\sqrt{x}} + ce^{-d\sqrt{x}}$
- **Part C**: `curvefit_dataset3.csv` to $A\sin(\omega x+\phi)$. (*Hint: In this case it's very important to give initial guesses for the parameters due to the fit function getting stuck in local minima during fitting*)

Question 2: Open the data files `co60.csv`, `cs137.csv`, and `na22.csv`. These files contain data similar to the Example 2 in the `Curve_Fitting_Examples.ipynb` file. Each represents count data from a separate radioactive substance: cobalt 60 (used in old radiotherapy units), Cesium 137, and Sodium 22.

- **Part A**: Plot the number of counts vs. the channel number for all three substances on the same plot.
- **Part B**: (Look only at channel numbers beyond 100). You will notice that `cs137` has one bump, while `na22` and `co60` have two bumps. Fit these 5 bumps to a Gaussian curve, finding μ and σ for each. Use the fact that the error on the number of counts N is $\sqrt{N}$ when fitting.
- **Part C**: It is known that Cobalt has emission energies 1.173MeV and 1.332MeV, Cesium has an emission energy of 0.6617MeV. and sodium has emission energies 0.511MeV and 1.275MeV. Match each of these energies E with μ from Part B, and plot μ vs. E. Then fit this data to a line $\mu = aE + b$ (using the fact that the error for μ is the fit error: `popt`).
- **Part D**: The fit $\mu = aE + b$ allows one to convert between units of channel number and units of energy. Convert the σ and μ from Part B to units of energy, and then plot σ vs. μ.
- **Part E**: By interpolating the data from Part D, find the detector resolution (i.e. σ) in units of energy at an incoming photon energy of 1MeV

Question 3: This question is for those who wish to better understand the theory behind the `curve_fit` function and error on the fit parameters.

- **Part A**: In curve fitting, one often hears the phrase "minimize the chi squared distribution". Let's take a look at this distribution. Using `from scipy.stats import chi2` plot the χ^2 distribution with the `chi2.pdf` function with `df = 18` degrees of freedom.

- **Part B**: Now let's create some simulated data; to create 20 data points that follow the distribution $y = 3e^{-2x}$ with error $\sigma = 0.1$ on each data point, use

```
x_data = np.linspace(0, 2*np.pi, 20)
yerr_data = 0.1*np.random.randn(len(x_data))
y_data = 3*np.exp(-2*x_data) + yerr_data
```

  and plot the corresponding errorbar plot. Fit the function to $y = ae^{-bx}$ and obtain the best fit parameters.

- **Part C**: Compute the value of χ^2 for the fit above using

$$\chi^2 = \sum (f(x_i;\beta) - y_i)^2/\sigma_i^2$$

  and see where this value lies on the plot from Part A (x-axis).

- **Part D**: Create a function `get_chi2` that creates data (like in part B) and returns the corresponding χ^2 fit value (like in Part C). Using a forloop, get 1009 different χ^2 values and plot them on a histogram using `plt.hist` with the argument `density=True` and `bins=100`. Plot the curve from part A over top.

Interlude: As you can see, for each obtained set of data, the value of χ^2 computed during the curve fitting follows a very particular distribution. We'll now see how this is related to the error on the parameter fit.

- **Part E**: Follow the instructions from Part B and C again to obtain a set of data, best fit parameters a_{opt} and b_opt, error on these parameters δ_a and δ_b using `np.sqrt(np.diag(pcov))`.

- **Part F**: Now write a function that fits data *to the one parameter function* $(a_{\text{opt}} + \delta_a)e^{-bx}$. (The interpretation here is that we're changing the optimal value of a by its error δ_a and seeing how that affects b). Compute the new χ^2 value and show that it's approximately one greater than the χ^2 value from Part E. (*Note*: It will not be exactly one greater, since the error on the parameters is only estimated in the `curve_fit` function)

Conclusion: This is precisely how the error on the parameters is defined: it is the amount by which you must change the best fit parameter (and re-optimize the other parameters) such that the value of χ^2 increases by exactly 1. ()