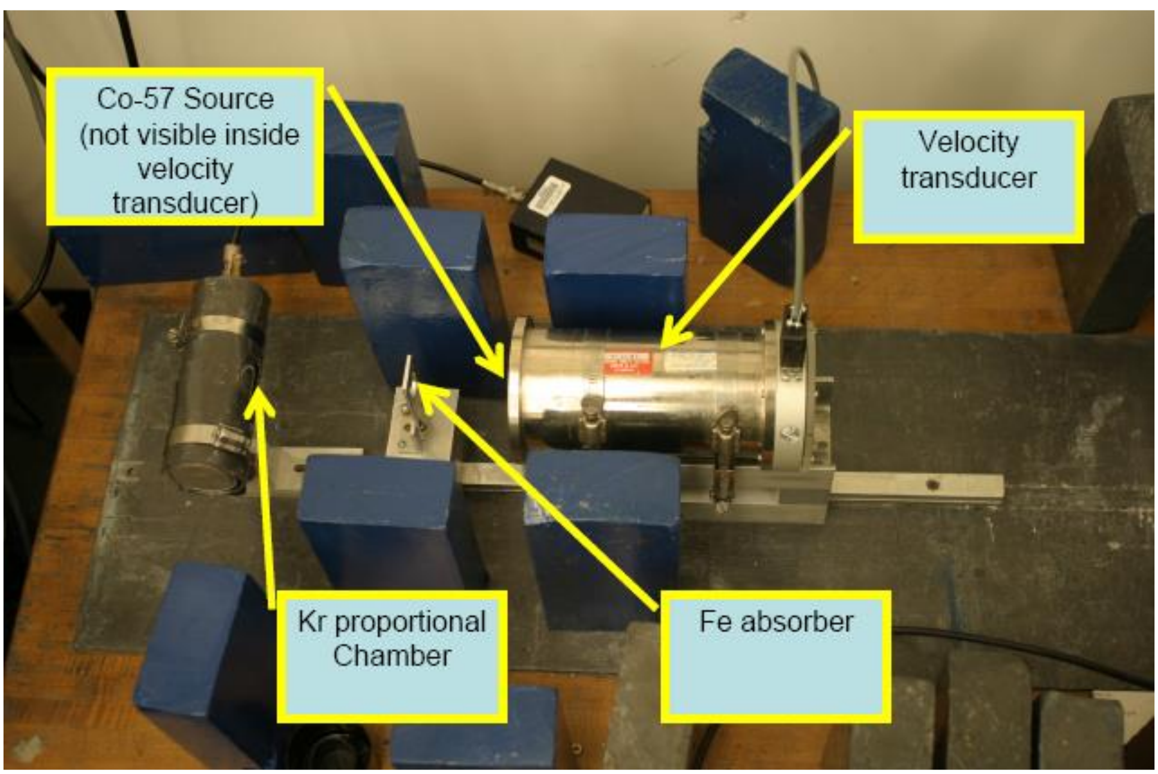
Mossbauer Lab Manual

Read the TEXTBOOK.

The section in Melissinos has a very good discussion of the Mossbauer effect and how to measure it. The setup described in the text is very close to the setup we employ here. The main difference is that the experiment in Melissinos uses a sterio speaker for the velocity transducer, while we use a commercial velocity transducer, which is more accurate.

Outline of experiment

The experiment consists of three sections. In the first section you will use a pulse height analyzer to measure the energy spectrum emitted by the radioactive $^{57}Co/^{57}Fe$ source. You will then put a copper foil absorber between the source and the detector in order to calibrate the energy scale by seeing where the Cu k-alpha x-ray peak occurs. After calibrating the energy scale you will set upper level and lower level discriminators so that you only count the 14.4 keV nuclear gamma rays and not the other x-rays. In the second section you will measure the transmission of various iron containing foils as a function of the relative velocity between the absorber foil and the moving source. In the final section you will analyze these absorption results in terms of the theory of Mossbauer spectra.



Calibration of pulse heights

The computer has a board which reads the heights of pulses from the spectroscopy amplifier in the electronics crate. The board can function in two different modes. In the PHA (pulse-height analysis) mode the board sorts the incoming pulses into bins depending on their pulse height, which is proportional to the energy of the gamma or x-ray which was absorbed in the proportional detector. The first part of the lab requires determining a calibration between energy and bin number so as to only measure gamma rays corresponding to the 14.4 keV nuclear transitions in ^{57}Fe. The radioactive source made up of ^{57}Co ^{57}Fe Rh alloy. The detector is a Kr filled gas proportional detector. There are several different energy radiations which will simultaneously hit the detector. You should see a 122 KeV gamma ray from the decay of ^{57}Co. This should be so high in energy that you don't directly see it in your proportional detector. You will also see the K x-rays from Fe, Co and Rh. In addition, you might see a peak corresponding to an "escape peak". This happens when a Kr atom in the detector absorbs an incoming gamma or x-ray and then emits its own characteristic x-ray which is lost from the detector. Thus the detector only measures the difference in energy between the two radiations.

To calibrate the source energy based on x-ray lines, measure the PHA spectra first without, and then with a Copper absorber foil. You may need to collect the spectra overnight to get good enough energy resolution.

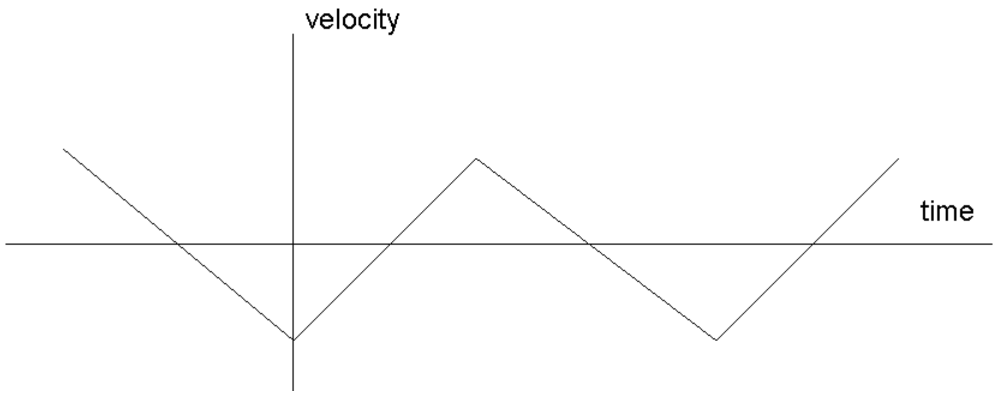
Instructions on how to save data and convert it to ASCII are given below. Note that in addition to converting the data to ASCII on the computer in the Mossbauer lab, this can possibly be done using matlab, please speak with the instructor if you want to try this.

The two spectra (with and without the copper) should look similar except there will be an additional peak due to the copper k-alpha x-rays at around 8 keV. You should thus have spectra which show peaks from Fe k-alpha and Cu k-alpha x-rays, Fe gamma rays (14.4 keV) and Rh k-alpha x-rays. Plot the known energies of these peaks against the channel numbers at which they occur. If you have made the correct assignments, you should be able to fit a straight line to your figure of the form

$$E = A(Ch - Offset) \tag{1}$$

Accumulate Mossbauer data in Multi-channel Scaler mode

In order to measure the Mossbauer spectra you need to measure how many of the Fe 14.4 keV gamma rays are absorbed for each value of the source velocity. This is done by having the velocity of the radioactive source follow a triangular wave as show in the figure below.



The computer then collects the number of gamma rays transmitted through the absorbing foil and bins them according to which phase in the cycle of the triangular wave they are collected. For example all gamma rays collected between $0 < \theta < 2\pi/1024$ go into the first bin, all gamma rays collected between $2\pi/1024 < \theta < 4\pi/1024$ in the second bin, $4\pi/1024 < \theta < 6\pi/1024$ the third bin etc. For the second period of the triangle wave the data are added on top of those from the first period etc. until sufficient statistics are acquired. Thus, each bin in the MCA spectrum corresponds to a specific velocity of the source relative to the absorber. (Note however, since the velocity repeats itself twice during each cycle of the oscillator, there will be two different bins corresponding to each value of the velocity.) If there is a dip in the pattern of intensity vs. bin number then this corresponds to a velocity at which the gamma rays are more strongly absorbed in the foil due to nuclear resonant absorption.

Once you have preliminary data, you may want to go back and try to optimize the LLD and ULD settings, or the range of the velocity transducer to get optimal data.

Magnetic Interaction Hamiltonian for the Mossbauer Effect

The energy of a magnetic dipole in a magnetic field is given by

$$E = -\vec{\boldsymbol{\mu}} \bullet \vec{\boldsymbol{B}} = -\frac{\mu}{I} B_z m_I$$

Where B_z is the magnetic field at the iron nucleus, μ is the magnetic moment , I is the nuclear spin of the energy level, and m_I is the *z*-component of the nuclear spin.

For the ground state, $I_g = \frac{1}{2}$ and $\mu_g = 0.090604$ nuclear magnetons
For the excited state, $I_e = \frac{3}{2}$ and $\mu_e = -0.15531$ nuclear magnetons

The conversion factor from nuclear magnetons to eV/gauss is:

1 nuclear magneton = 3.15245×10^{-12} eV/gauss

The B field is given in gauss.

Some Results to aim for in this lab

1. Explain the peaks you see in the PHA graphs.
2. Measure the Mossbauer spectrum of magnetic Fe.
3. Measure the Mossbauer spectrum of non-magnetic Fe.
4. Explain the difference between the two.
5. Extract the energy differences between the different absorption lines using the Doppler shift and the relative velocity of the source and absorber.
6. Explain why there are 6 Mossbauer lines.
7. Explain why the 6 lines are doubled in the spectra you see
8. Compare the relative intensities of the absorption lines.
9. Measure the energy width of the absorption lines.
10. Extract the absorption cross section from the depth of the dip in the spectrum (for this you need the thickness of the absorber).
11. **Find the internal magnetic hyperfine field of the iron nucleus**

Procedure:

1. Calibrate the Energy spectrum

(a) Put the system in MCA mode (click the "system options" key)

(b1) Measure energy spectrum of just the source (no sample).

(b2) Measure energy spectrum of Natural Iron Foil (baseline measurement)

(c) Measure energy spectrum of several other foils

(d) Use X-ray Data Booklet to determine the emission lines in each spectrum

(e) Make plot of Energy vs. channel number -- this is your calibration

(f) Determine at which channel # is the nuclear resonance signal

2. Set the Discriminator levels

(a) Click on the tool key (Range, preset, ...) --- MCA Settings shows up

(b) Click on ADC

(c) Adjust Lower and Upper Level settings to allow only the nuclear resonance signal to be seen. The rest of the spectrum should be blocked out.

3. Start the Mossbauer Measurement

(a) Put the system in MCS mode (click the "system options" key)

(b) Press "start" to start measuring the Mossbauer spectrum.

(c) Measure the iron-based samples only (natural Fe-foil, Stainless steel, FeF, Iron-oxides, etc)

(d) Calibration for Mossbauer spectrum (counts vs. velocity)
one channel = 0.0432225 mm/sec
(potentiometer setting of 5.0 produces ***v(max/min) = +/- 8.633387*** mm/sec)

(e) Fold the data to improve the statistics

(f) **Find the internal magnetic hyperfine field of the iron nucleus**