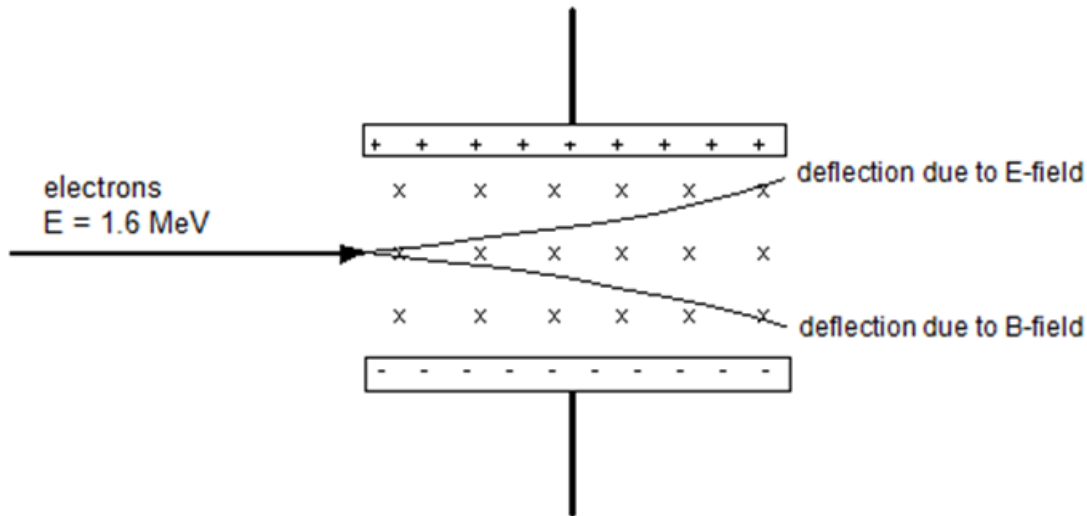


# ENERGY, MOMENTUM AND MASS

## STUDENT PAGE

### DESCRIPTION

Walter Kaufmann and Alfred Bucherer performed experiments in the early 20th century to determine the effect of electric fields and magnetic fields on moving electrons. In 1901, Kaufmann did an experiment to investigate the effect of changing energy on electrons in the 0.7 MeV to 1.6 MeV energy range. Later, Bucherer did a similar experiment, which included lower energy electrons. Note that Kaufmann took his data *before* the introduction of the special theory of relativity in 1905. In both cases, the experimenters measured energy by deflecting an electron beam with an electric field while momentum was derived by deflecting the beam with a magnetic field, as seen in Figure 1 below.



*Kaufman 1901 (0.7 < E < 1.6 MeV)*

*Bucherer 1905 (0.5 MeV < E < 0.7 MeV)*

Figure 1: Diagram of the Kaufmann and Bucherer experiments.

Your job is to determine the relationship between energy, momentum and mass using these data.

### What do we know?

- The path of the electrons in the electric field is used to determine the energy of the electron.
- The path of the electrons in the magnetic field is used to determine the momentum of the electron.
- The shape of graphed data gives evidence for how to modify the data to plot a linear graph.
- The units of the slope and intercept of a linear graph give evidence for the physical meaning of the slope and intercept values.

### What do we need?

- Data table

Source of Data	Energy MeV	Momentum MeV/c
Simulated	0.515	0.053
	0.52	0.08
	0.53	0.132
	0.54	0.158
Bucherer 1909	0.542	0.172
	0.552	0.209
	0.567	0.243
	0.593	0.305
	0.700	0.481
Kaufmann 1901	0.767	0.603
	0.848	0.700
	1.022	0.882
	1.237	1.121
	1.584	1.494

### What do we do?

- **Plot** energy (E) as a function of momentum (p).
- **Describe** the relationship between energy and momentum.
- **Use** the shape of the graph to determine how to modify the data to make a linear graph.
- **Plot** the modified data.
- If this graph is not linear, **use** the shape of this graph to determine how to modify the data to make a linear graph. (Get help: <https://quarknet.org/content/how-linearize-curved-data-plot>.)
- **Write** the equation of the linear graph using the slope value and intercept value. Remember units on values!
- **Describe** the physical meaning of the slope of the linearized graph. Use the units as a clue.
- **Describe** the physical meaning of the intercept of the linearized graph. Remember that when momentum equals zero, the electron is at rest in the reference frame. Use the units as a clue.
- **Make** a claim about the relationship between m, p, and E. Support your claim with evidence and reasoning.