electric or magnetic field suggested that cathode rays could be charged particles; and the direction of the deflection was consistent with a negative charge. Furthermore, if the tube contained certain types of rarefied gas, the path of the cathode rays was made visible by a slight glow.

Estimates of the charge e of the (assumed) cathode-ray particles, as well as of their charge-to-mass ratio e/m, had been made by 1897. But in that year, J. J. Thomson (1856–1940) was able to measure e/m directly, using the apparatus shown in Fig. 27–2. Cathode rays are accelerated by a high voltage and then pass between a pair of parallel plates built into the tube. The voltage applied to the plates produces an electric field, and a pair of coils produces a magnetic field.

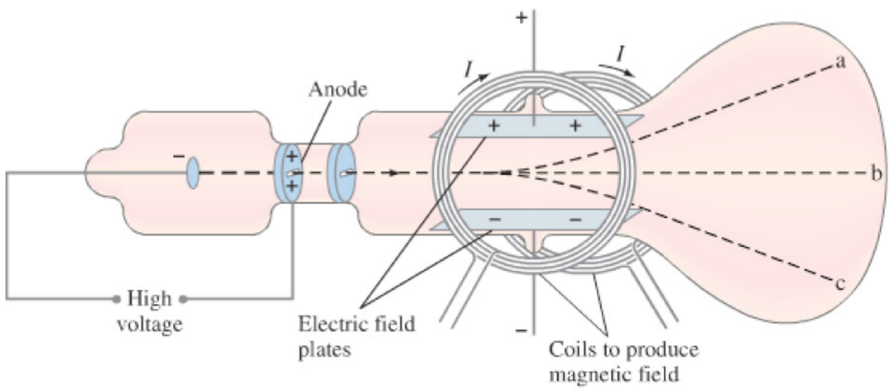

FIGURE 27–2 Cathode rays deflected by electric and magnetic fields.

When only the electric field is present, say with the upper plate positive, the cathode rays are deflected upward as in path a in Fig. 27–2. If only a magnetic field exists, say inward, the rays are deflected downward along path c. These observations are just what is expected for a negatively charged particle. The magnitude of force on the rays due to the magnetic field is $F_{\text{mag}} = evB$, where e is the charge and v is the velocity of the cathode rays (Eq. 20–4). In the absence of an electric field, the rays are bent into a curved path, and applying Newton's second law $F = ma$ to a cathode ray gives

$$evB = m\frac{v^2}{r},$$

and thus

$$\frac{e}{m} = \frac{v}{Br}.$$

The radius of curvature r can be measured and so can B. The velocity v can be found by applying an electric field in addition to the magnetic field. The electric field E is adjusted so that the cathode rays are undeflected and follow path b in Fig. 27–2. In this situation the upward force due to the electric field, $F_{\text{el}} = eE$, is balanced by the downward force due to the magnetic field, $F_{\text{mag}} = evB$. We equate the two forces, $eE = evB$, and find

$$v = \frac{E}{B}.$$

Combining this with the above equation we have

$$\frac{e}{m} = \frac{E}{B^2 r}. \qquad \textbf{(27–1)}$$

e/m measured

The quantities on the right side can all be measured, and although e and m could not be determined separately, the ratio e/m could be determined. The accepted value today is $e/m = 1.76 \times 10^{11}\ \text{C/kg}$. Cathode rays soon came to be called **electrons**.

"Discovery" of the electron

The "discovery" of the electron, like many others in science, is not quite so obvious as discovering gold or oil. Should the discovery of the electron be credited to the person who first saw a glow in the tube? Or to the person who first called them cathode rays? Perhaps neither one, for they had no conception of the electron as we know it today. In fact, the credit for the discovery is generally given to Thomson, but not because he was the first to see the glow in the tube.