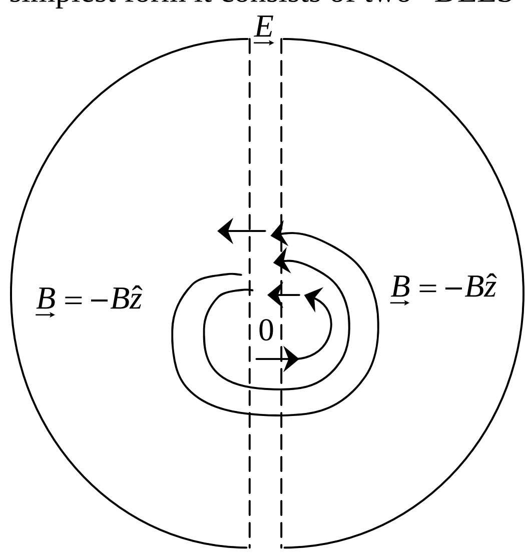
Devices $\vec{E}$ using and $\vec{B}$ fields

CYCLOTRON

This device works because the angular velocity of a charge moving in a $\vec{B}$ field is <u>independent</u> of its speed.

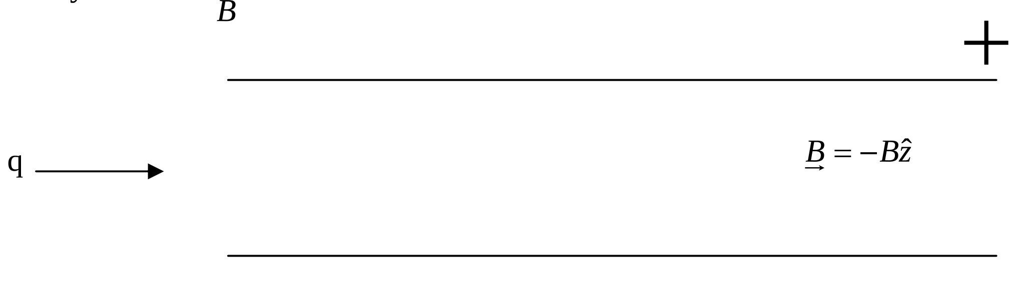
$$\vec{F}_C = -\frac{MV^2}{r}\hat{r} \text{ is provided by}$$
$$\vec{F}_B = -qVB\hat{r}$$
$$\text{So} \qquad \omega = \frac{V}{r} = \frac{qB}{M}$$

The cyclotron combines a $\vec{B}$ and an $\vec{E}$-field. In its simplest form it consists of two "DEES" in which there is constant $\vec{B}$-field. Say $\vec{B} = -B\hat{z}$. In the gap between them there is an $\vec{E}$-field which varies with time at the same angular frequency $\omega = \left(q\frac{B}{M}\right)$. Suppose at 0 you have a positive charge q which you accelerate with an $\vec{E}$-field so it enters the right DEE with a velocity $V\hat{x}$. The $\vec{B}$-field will make it go around a $\odot$ with angular velocity ω. By the time it arrives in the gap $\vec{E}$ will have reversed as the period of $\vec{E}$ is the same as $\frac{2\pi}{\omega}$ so q will get accelerated again. In this way the charge goes round and round within the DEES and gets accelerated each time it crosses the gap. Indeed this device can accelerate charges to quite high speeds.



VELOCITY SELECTOR

This again uses a combination of $\vec{E}$ and $\vec{B}$ and produces a beam of charges with a fixed speed controlled by the ratio $\frac{E}{B}$.



We begin with two parallel plates and establish an $\underset{\rightarrow}{E}$ field between them

$$\underset{\rightarrow}{E} = -E\hat{y}$$

Introduce a beam of charges q with a distribution of velocities along the x-axis. Once they enter the $\underset{\rightarrow}{E}$ field they will experience a force

$$\underset{\longrightarrow}{F_E} = -qE\hat{y} \qquad \text{-(1)}$$

(Recall problem 4-5) which will make them bend downward. Now, we introduce a $\underset{\rightarrow}{B} = -B\hat{z}$ between the plates. It will cause the particles to experience a force

$$\underset{\longrightarrow}{F_B} = qvE\hat{y} \qquad (2)$$

If we choose $\underset{\rightarrow}{B}$ correctly, we can make

$$\underset{\longrightarrow}{F_B} + \underset{\longrightarrow}{F_E} = 0 \quad \rightarrow \qquad (3)$$

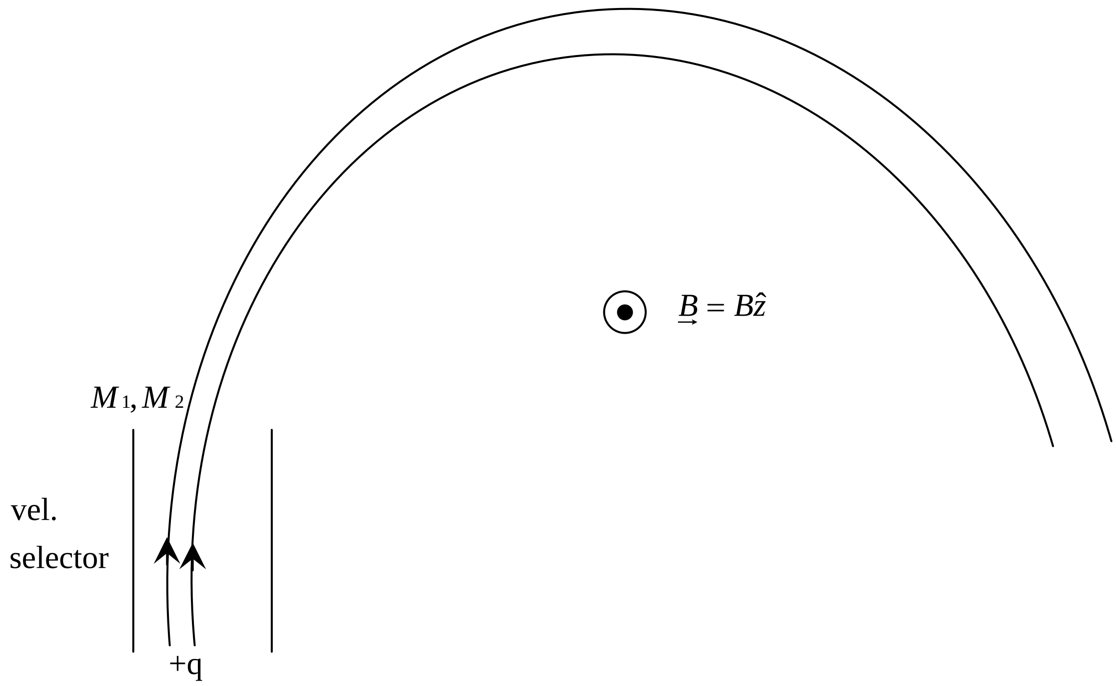
Hence a charge whose speed satisfies Eq (3) will go between the plates straight through, that is if

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

the charge goes through. If V is larger $F_B > F_E$ charge will hit top plate, if $V < \frac{E}{B}$ charge will hit bottom plate.

MASS SPECTROMETER

This device is used to separate beams of isotopes, that is charged particles whose masses re different. Let us say we have a beam of charges q with two masses M_1 and M_2. The device is as below.



First, use a velocity selector so both masses have velocity $\underset{\to}{V} = V\hat{y}$. Next, apply $\underset{\to}{B} = B\hat{z}$ it will make the charges go on circles of radii

$$R_1 = \frac{M_1 V}{qB} \quad \text{and} \quad R_2 = \frac{M_2 V}{qB}$$

thereby separating them. It can also be used to separate two charged beams where particles have the same mass.