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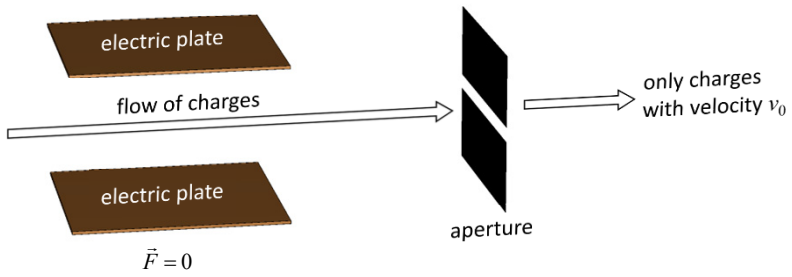
Electromagnetics:
Electromagnetic Field Theory

Example 1 – Velocity Filter

1

Example #1 – Velocity Filter

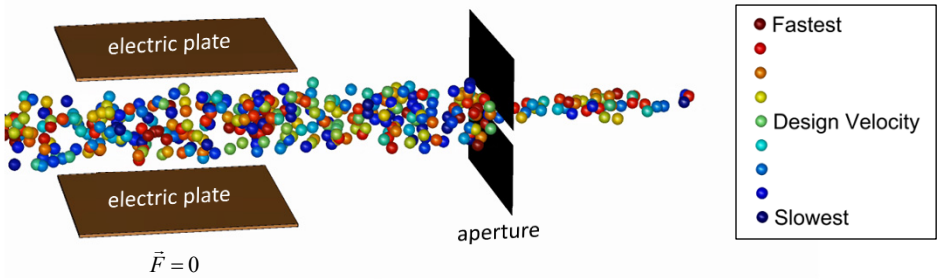
Suppose it is desired to create a "bandpass" velocity filter where the system only passes charges moving with velocity 4 m/s and deflects all others.



2

Example #1 – Velocity Filter

Without any applied field, charges flow in a straight line and charges of all velocities are passed by the aperture.



$\vec{F} = 0$

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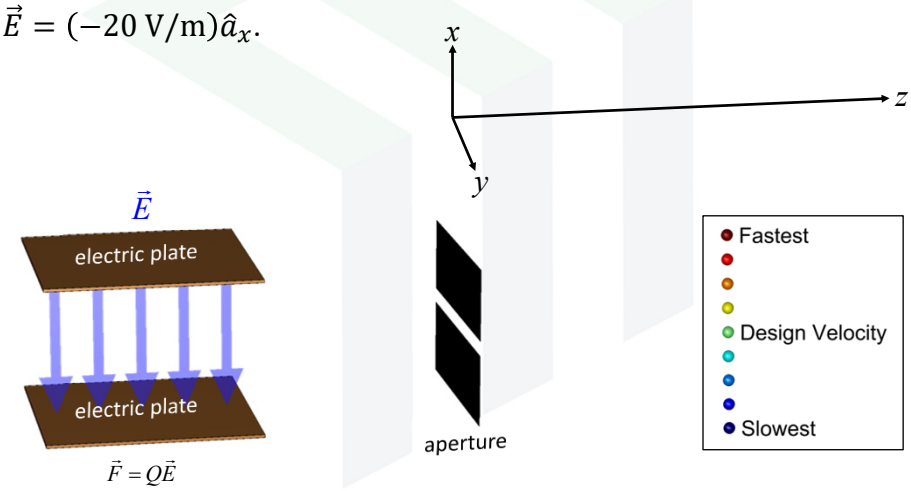
Slide 3

3

Example #1 – Velocity Filter

Now apply an electric field in the vertical direction.

Let this be $\vec{E} = (-20\ \mathrm{V/m})\hat{a}_x$.



$\vec{F} = Q\vec{E}$

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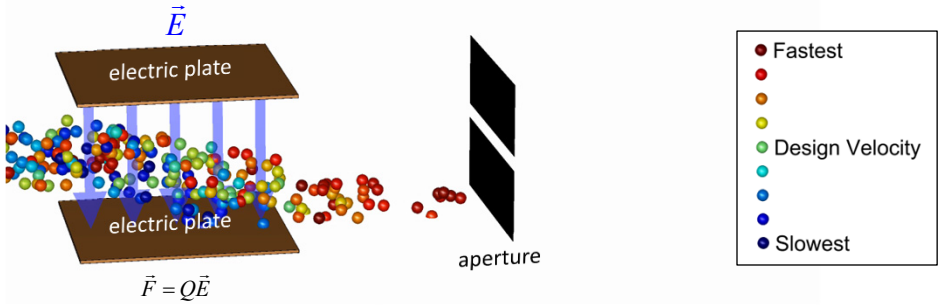
Slide 4

4

Example #1 – Velocity Filter

All charges experience the same force in the downward direction.

Particles spread according to velocity due to inertia, not due to a velocity dependent force.



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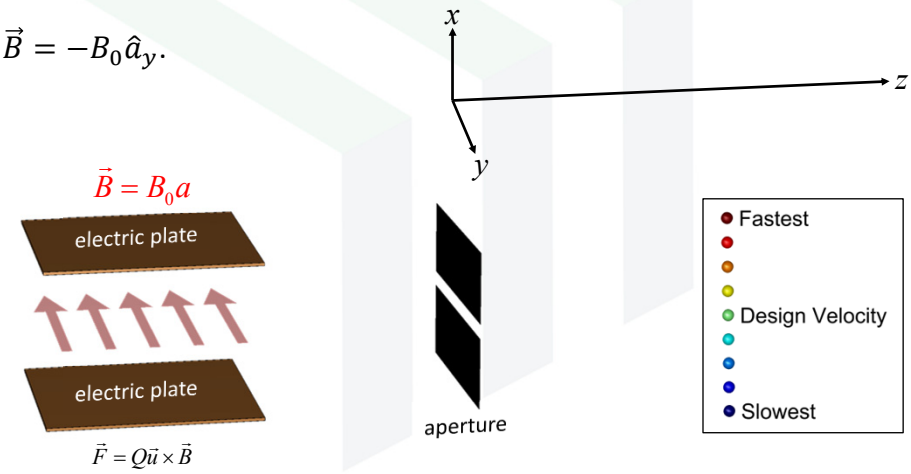
Slide 5

5

Example #1 – Velocity Filter

It is desired to calculate the magnetic field who's force will exactly oppose the force due to the electric field at the design velocity.

Let this be $\vec{B} = -B_0 \hat{a}_y$.



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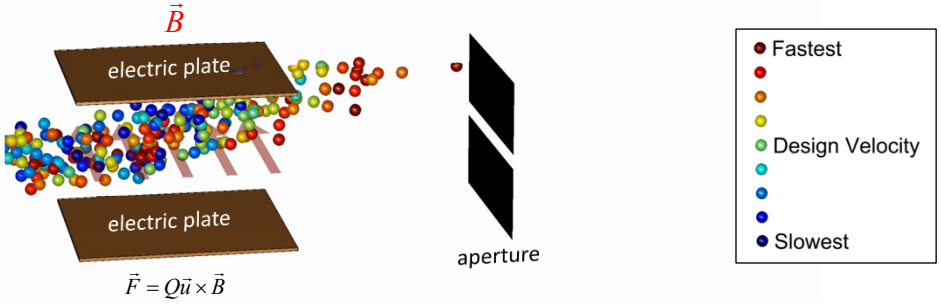
Slide 6

6

Example #1 – Velocity Filter

With just the magnetic field applied, all charges experience a force in the upward direction, but that force is proportional to the velocity.

Deflection appears more uniform because the inertia and velocity dependent force counteract each other.



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Slide 7

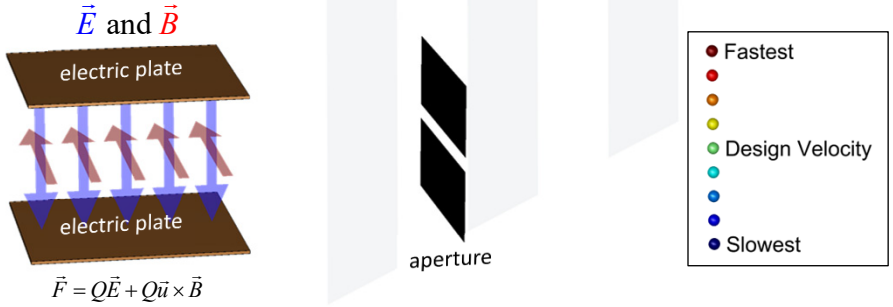
7

Example #1 – Velocity Filter

The net force should be zero at the design velocity.

$$0 = Q\vec{E} + Q\vec{u} \times \vec{B}$$
$$= \vec{E} + \vec{u} \times \vec{B} = -(20\ \text{V/m})\hat{a}_x + (4\ \text{m/s})\hat{a}_z \times (-B_0)\hat{a}_y = -20\hat{a}_x + 4B_0\hat{a}_x$$

$$\boxed{B_0 = 5\ \text{Wb/m}^2}$$



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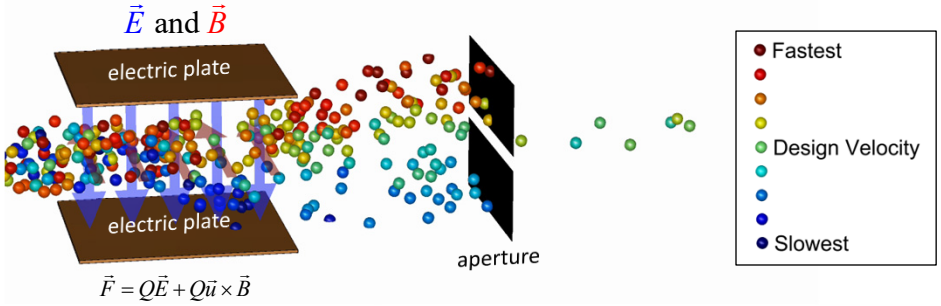
Slide 8

8

Example #1 – Velocity Filter

The forces due to the fields counteract each other such that the charges moving at the design velocity experience zero net force and are not defected.



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Slide 9

9