
# Physics 2102

## Magnetic fields

# Question

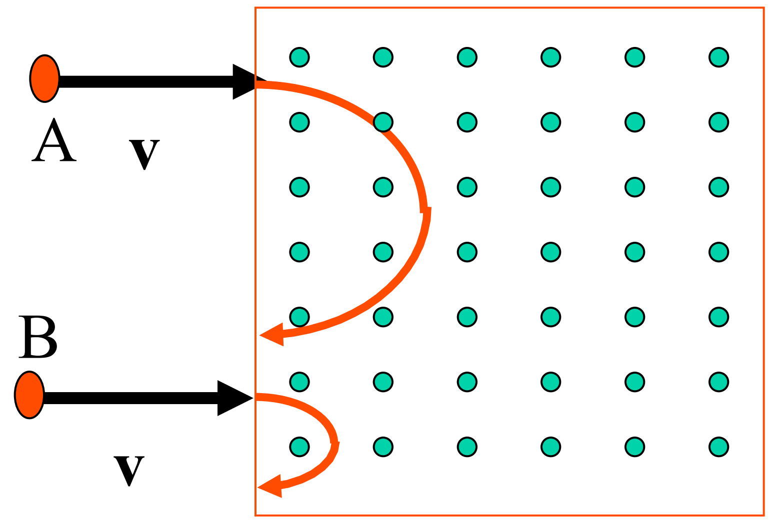
Two charged ions A and B traveling with a constant velocity **v** enter a box in which there is a uniform magnetic field directed out of the page. The subsequent paths are as shown. What can you conclude?

(a) Both ions are negatively charged.

(b) Ion A has a larger mass than B.

(c) Ion A has a larger charge than B.

(d) None of the above.




$$F_B = q\, \boldsymbol{v} \times \boldsymbol{B}$$

$$r = \frac{mv}{qB}$$

(a) F=qv x B.
The vector v x B will point down when the charges enter the box; the force also points down for cw motion: charges must be positive.

(b,c) r= mv/qB
Same speed and B for both masses; larger radius for A than B. Ion with larger mass/charge ratio (m/q) moves in circle of larger radius. But that's all we know! We cannot conclude b or c.

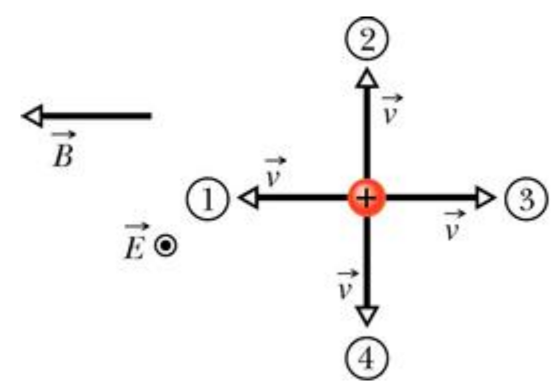
(d) Is the right answer.

# Crossed fields

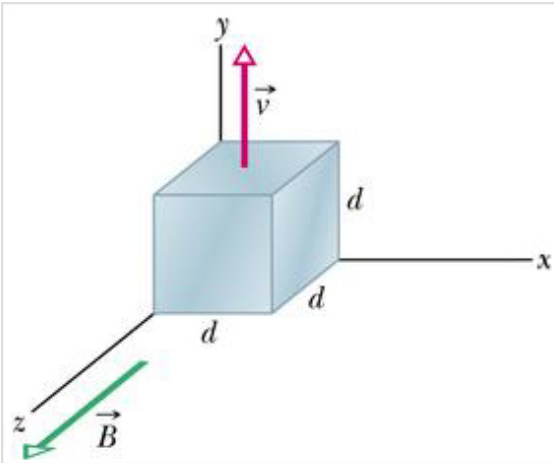
The figure shows four directions for the velocity vector v of a positively charged particle moving through a uniform electric field E (out of the page) and a uniform magnetic field B.

- Rank directions 1, 2, 3 according to the magnitude of the net force on the particle.

- If the net force is zero, what is the direction and magnitude of the particle's velocity?



# Electric and magnetic forces: example




A solid metal cube moves with constant velocity v in the y-direction. There is a uniform magnetic field B in the z-direction.

a) What is the direction of the magnetic force on the electrons in the cube?
b) What is the direction of the electric field established by the electrons that moved due to the magnetic force?
c) Which cube face is at a lower electric potential due to the motion through the field?
d) What is the direction of the electric force on the electrons inside the cube?
e) If there is a balance between electric and magnetic forces, what is the potential difference between the cube faces (in terms of the cube's velocity v, side length d and magnetic field B)?

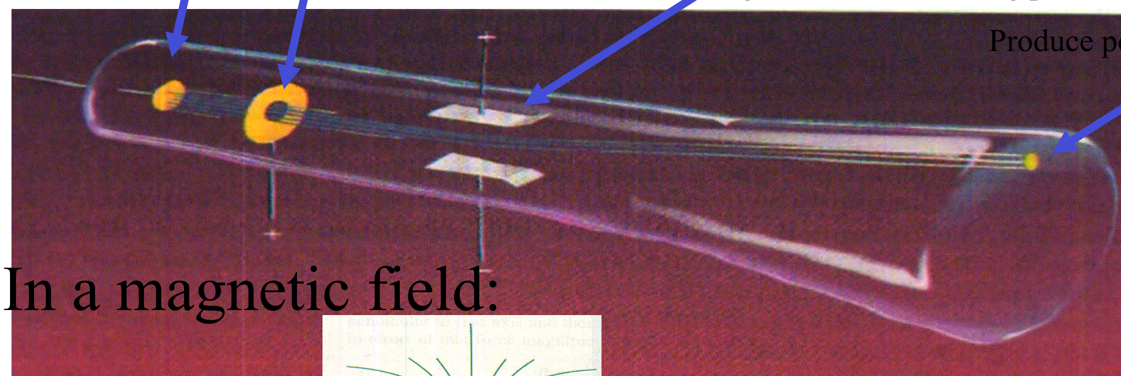
# Cathode ray tube (CRT) : TV, computer monitors before LCD

Hot cathode emits electrons

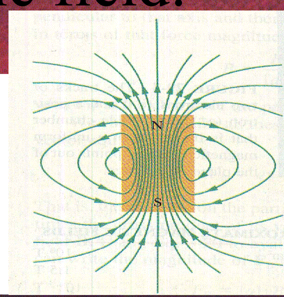
Get accelerated by positive plate

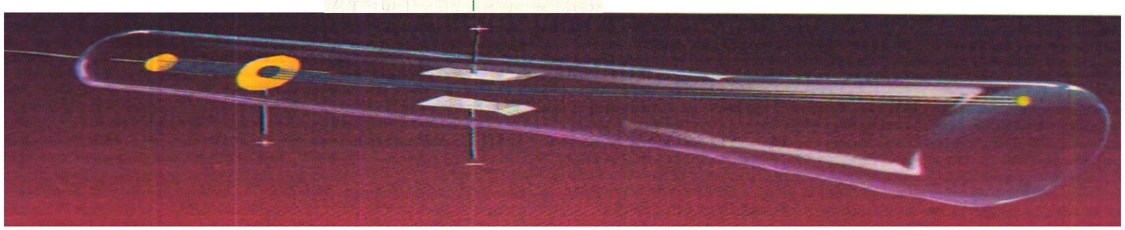
Might be deflected using plates

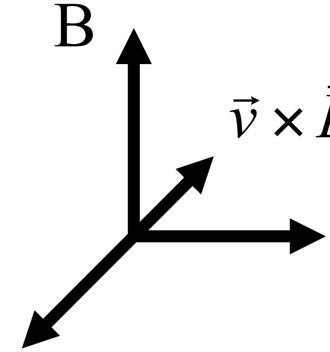
Produce point of light on screen.



In a magnetic field:



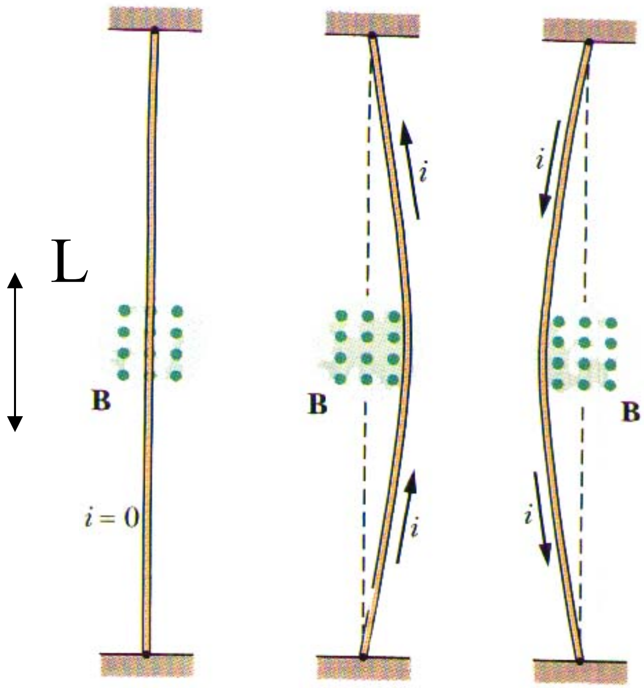





Dot shifts sideways.

http://en.wikipedia.org/wiki/Comparison_of_display_technology

# Magnetic force on a wire




$$q = i\,t = i\,\frac{L}{v_d}$$

$$\vec{F} = q\,\vec{v}_d \times \vec{B}$$

$$\vec{F} = q\,\frac{i\,\vec{L}}{q} \times \vec{B} = i\,\vec{L} \times \vec{B}$$

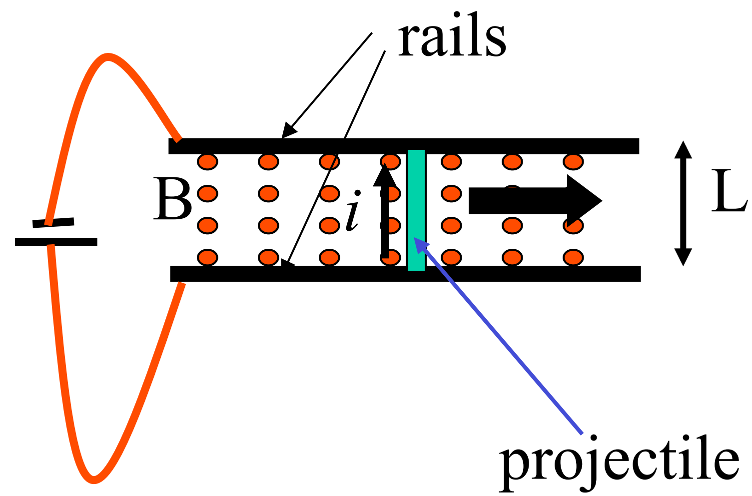
$$\vec{F} = i\,\vec{L} \times \vec{B}$$

Note: If wire is not straight, compute force on differential elements and integrate:

$$d\vec{F} = i\,d\vec{L} \times \vec{B}$$

# The Rail Gun

- Conducting projectile of length 2cm, mass 1g carries constant current 10A between two rails.
- Magnetic field B = 1T points outward.
- Assuming the projectile starts from rest at t = 0, what is its speed after a time t = 1s?




- Force on projectile = $iLB$ (from $\mathbf{F} = i\mathbf{L} \times \mathbf{B}$)
- Acceleration = $iLB/m$ (from $F = ma$)
- $v(t) = iLBt/m$ (from $v = v_0 + at$)

$$= (10A)(0.02m)(1T)(1s)/(0.001kg)$$

$$= 200 \text{ m/s} \sim 450 \text{ mph}$$

But: $d = 0.5(iLB/m)t^2 = 0.5\ v(t)\ t = 100$ m!!

# Rail guns in the "Eraser" movie

"Rail guns are hyper-velocity weapons that shoot aluminum or clay rounds at just below the speed of light. In our film, we've taken existing stealth technology one step further and given them an X-ray scope sighting system," notes director Russell. "These guns represent a whole new technology in weaponry that is still in its infancy, though a large-scale version exists in limited numbers on battleships and tanks. They have incredible range. They can pierce three-foot thick cement walls and then knock a canary off a tin can with absolute accuracy. In our film, one contractor has finally developed an assault-sized rail gun. We researched this quite a bit, and the technology is really just around the corner, which is one of the exciting parts of the story."

*Warner Bros., production notes, 1996.*
*http://movies.warnerbros.com/eraser/cmp/prodnotes.html#tech*

**Also: INSULTINGLY STUPID MOVIE PHYSICS: http://www.intuitor.com/moviephysics/**