It is possible to measure the force between the ends of two bar magnets, either as attraction or repulsion. It is found that the force varies inversely with the square of the distance between the poles, just as gravity and electricity do. Thus the force F is proportional to the strength of the magnet and inversely proportional to the square of the distance. A formula would look like

$$F = \frac{p}{r^2}$$

Raw Similarities with Electricity

a) Inverse square laws

b) Can define charge and pole strength in similar ways

c) Total pole strength = 0; electric charge is conserved

Raw Difference with Electricity

a) All bodies can be charged but only a few (Fe, Co, Ni..) can be magnetised.

b) Charge can flow from one place to another, pole strength cannot.

c) Magnetism is stable. A magnet stays a magnet essentially for ever

Electricity is not stable as bodies may lose their electric charge.

Hans Christian Ørsted


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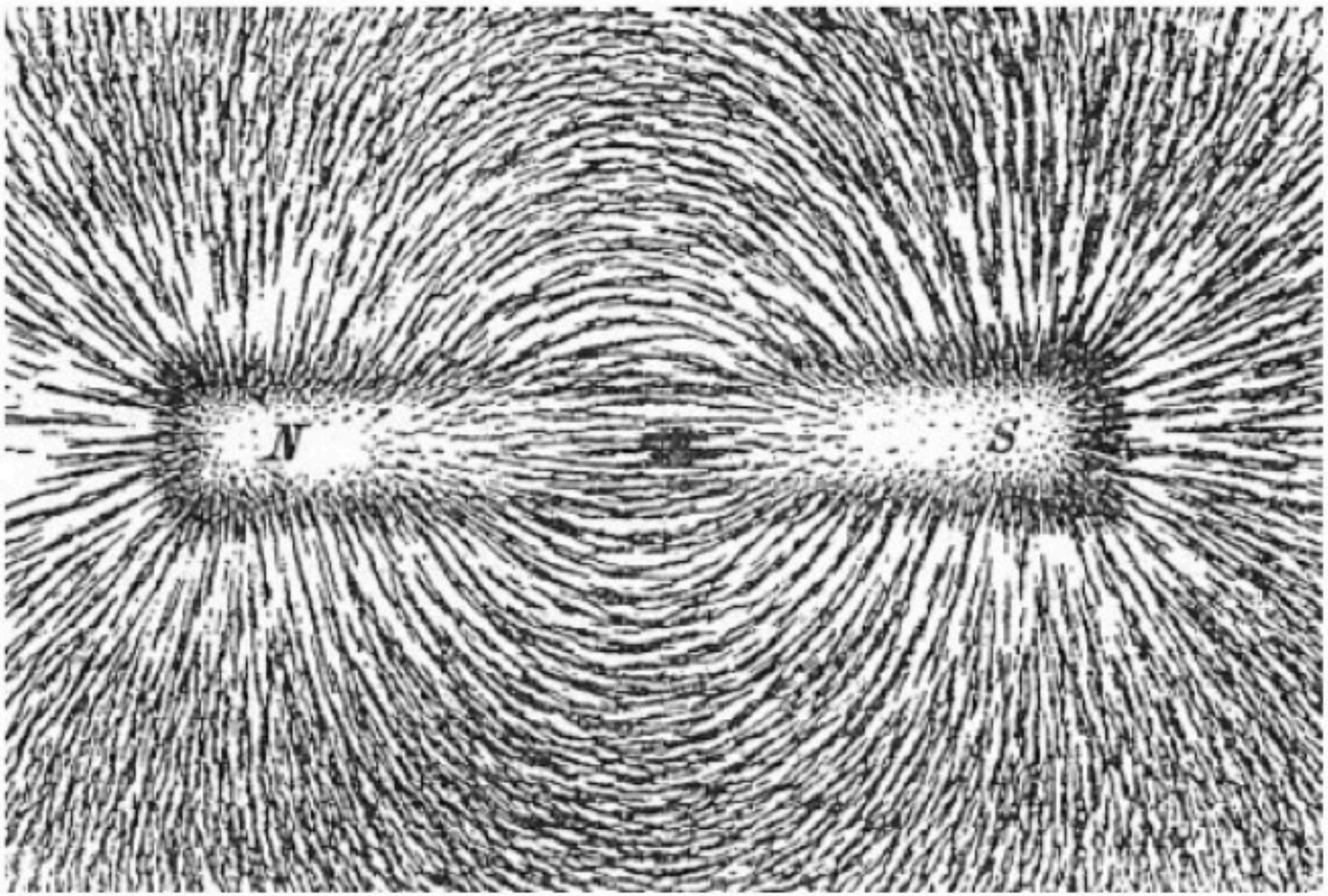
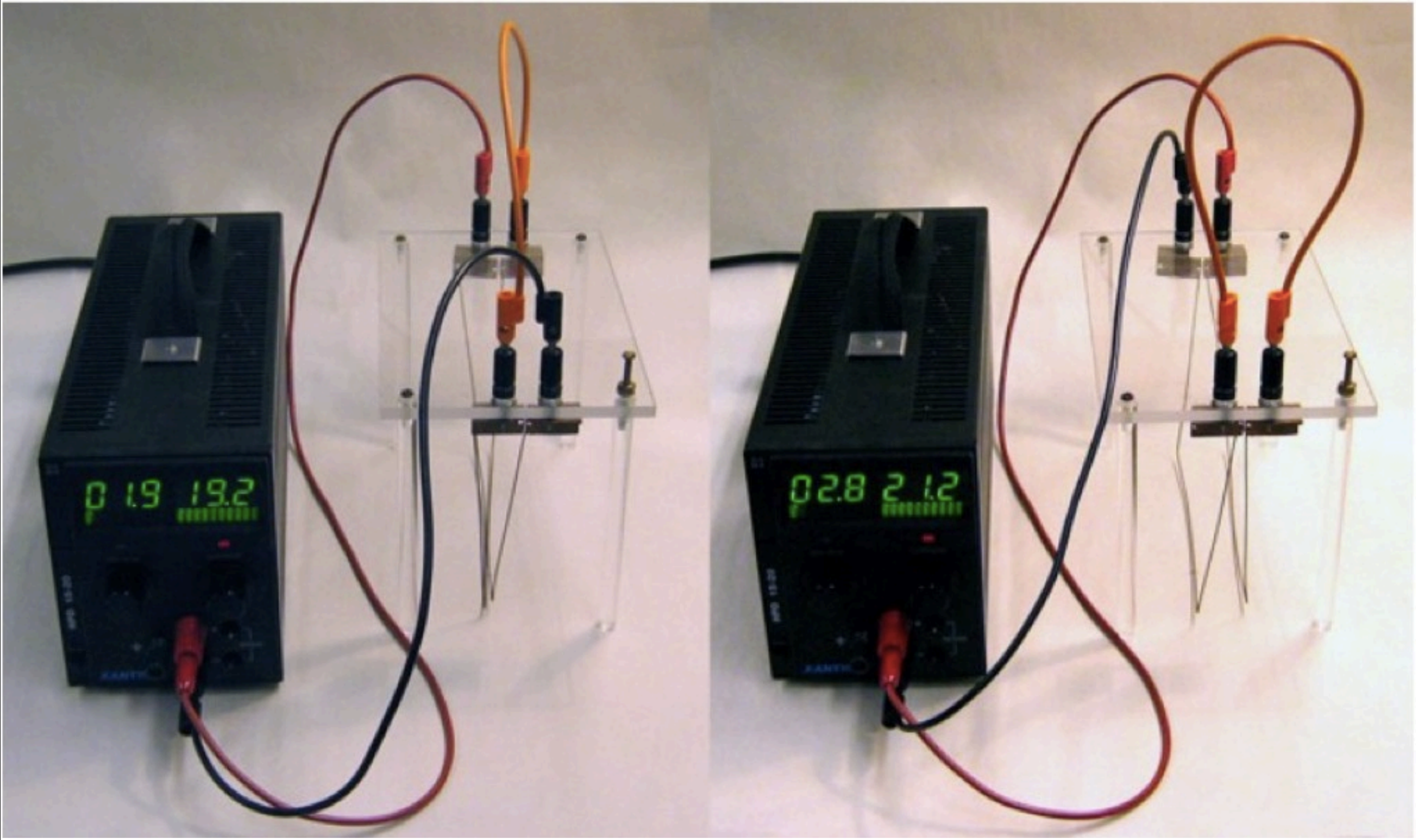

N
S

If one looks at the iron filings pattern around a bar magnet, it is easy to believe in the existence of a magnetic field in the space around the magnet. Since a current can affect such a magnet, there must be a similar field around a wire carrying current. In modern terms, a moving charge (an electric current) creates a magnetic field and a magnet near a current will experience a force. By Newton's 3rd Law, if the current creates a force on a magnet, then a magnet must create a force on a current carrying wire. Or, better said, a magnetic field can create a force on a moving charge.

Finally, since a moving charge both creates a field and can experience a force in a field, no bar magnets are necessary. ***One current will exert a force on another current!***


01.9 19.2
02.8 21.2

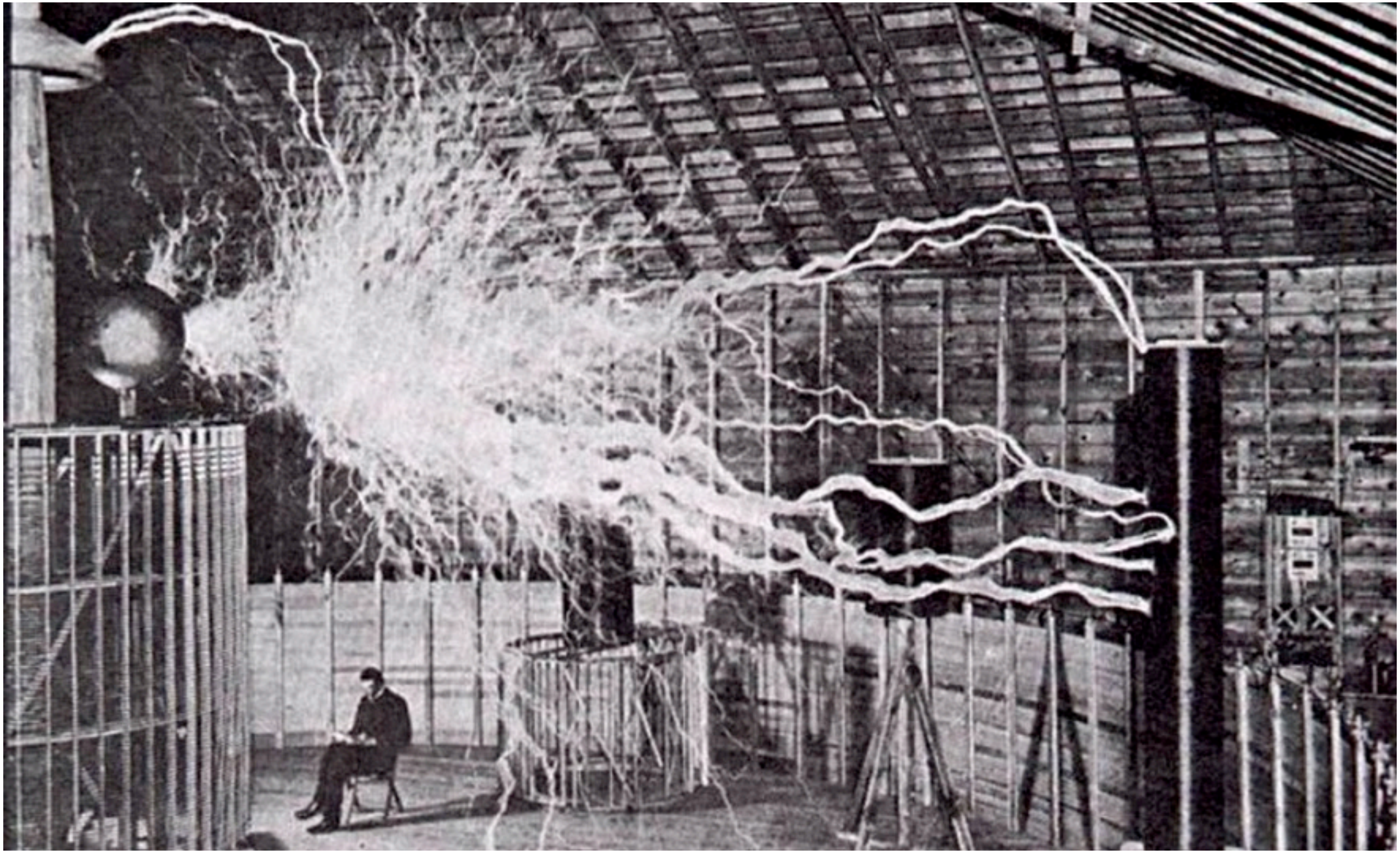
A bar magnet is divided in two pieces. Which of the following statements is true?

A. The bar magnet is demagnetised.
B. The magnetic field of each separated piece becomes stronger.
C. The magnetic poles are separated.
D. Two new bar magnets are created.
E. An electric field is created

Currents just mean charges are moving. So a magnetic field will exert a force on a moving charge. Or, one moving charge will exert a force on another moving charge, a magnetic force, rather than a standard electrical force. A force due to the *motion*, not the *presence* of the charge.

$$F = qv_{\perp} B = qvB\sin\vartheta \qquad \vec{F} = q\vec{v} \times \vec{B}$$

We use the symbol $\boldsymbol{B}$ to represent the magnetic field and we measure the field in units called **Tesla.** The angle $\vartheta =$ the angle between the velocity v and the field B. The $\sin\vartheta = 1$ when $\vartheta = 90^{\circ}$ and $= 0$ when $\vartheta = 0^{\circ}$. If you know what a cross product of two vectors is, then the relation between B and v is just such a cross product.



Nikolai Tesla (1856 - 1943)

And here is the problem that makes magnetism probably harder than either gravity or electricity.

Magnetic Field Problems are inherently THREE DIMENSIONAL.

So we will need ways to remember and account for all three dimensions.

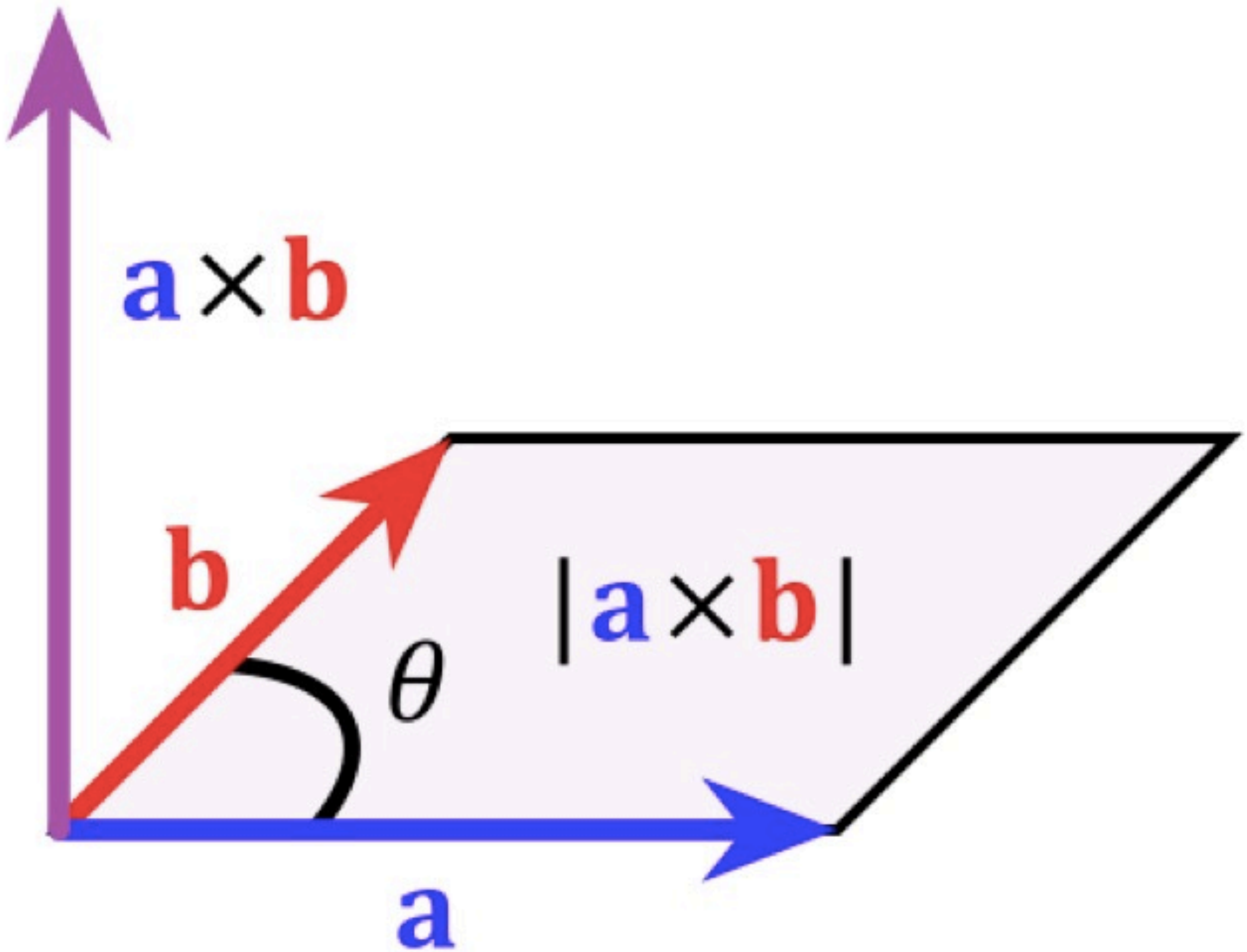
$$F = qv_{\perp}B = qvB\sin\vartheta$$

A particle moving parallel to the field experiences no force and moving perpendicular to the field experiences the maximum force. The direction of the force is found to be perpendicular to both the velocity and the field and we shall invent the Right Hand Rule to remember these directions.

The Right Hand rule:

1. Put your thumb in the direction of the velocity of the *positive* particle.
2. Put your first finger along the B field direction.
3. The force will be perpendicular to the palm of your hand, or the direction which the rest of your fingers will naturally point.

If the moving particle is *negative*, the force will be in the *opposite* direction.


a×b
b
θ
|a×b|
a

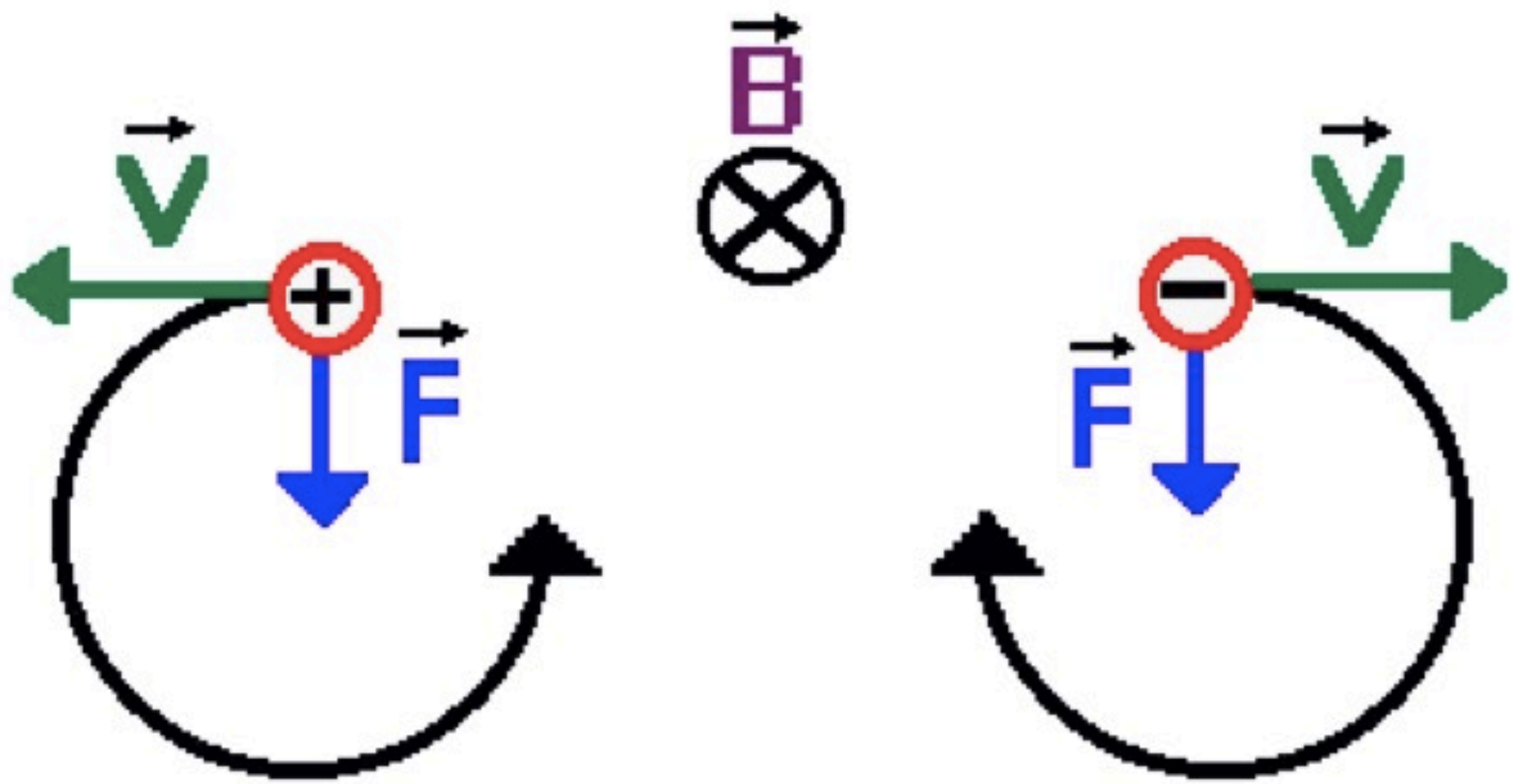
$\otimes$

Symbol for B field
into the paper

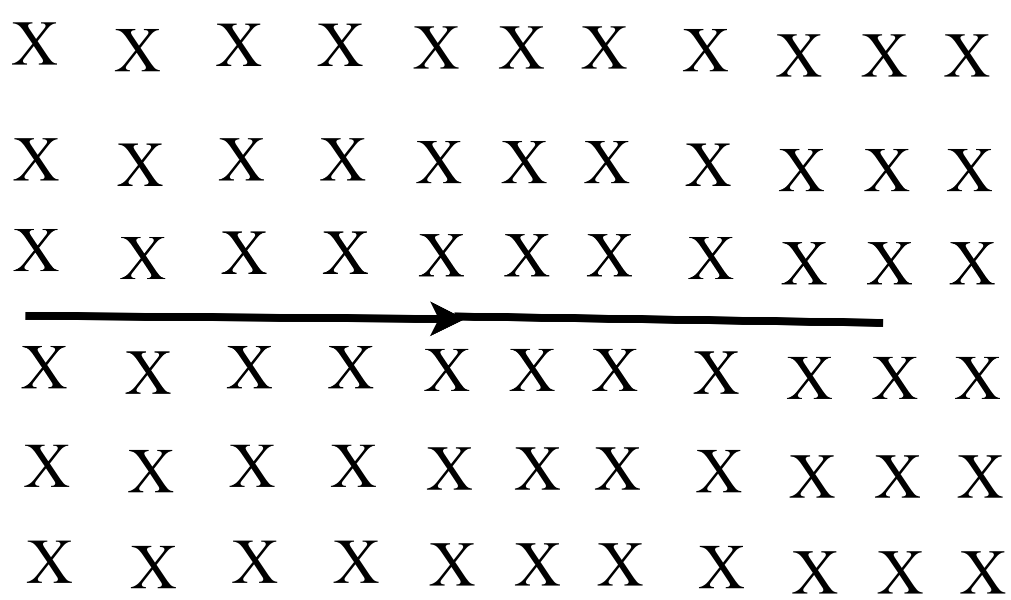
$\odot$

Symbol for B field
out of the paper

Currents create magnetic fields. Charges create electric fields. Charges in motion create both electric and magnetic fields. However, a current in a wire leaves the wire NEUTRAL, only the electrons are moving but the total charge on the wire is still zero. For every electron that leaves the wire, another enters. In this case, ONLY a magnetic field is created.

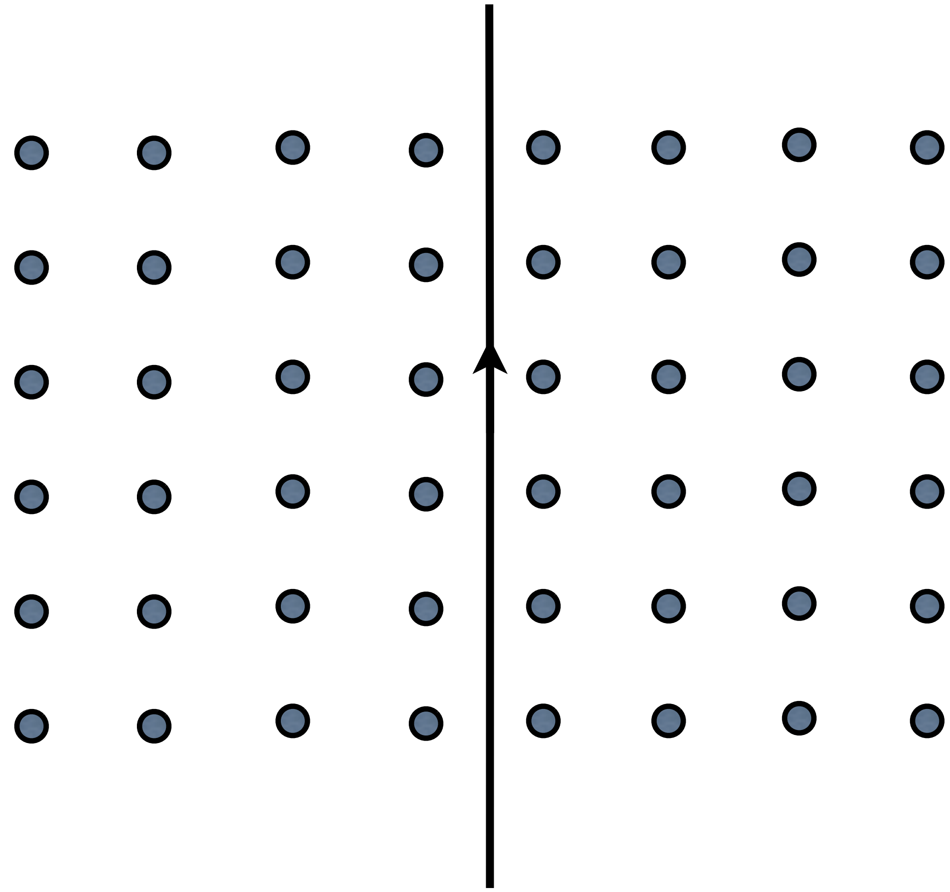


Since F is perpendicular to v, the motion must be in a circle.



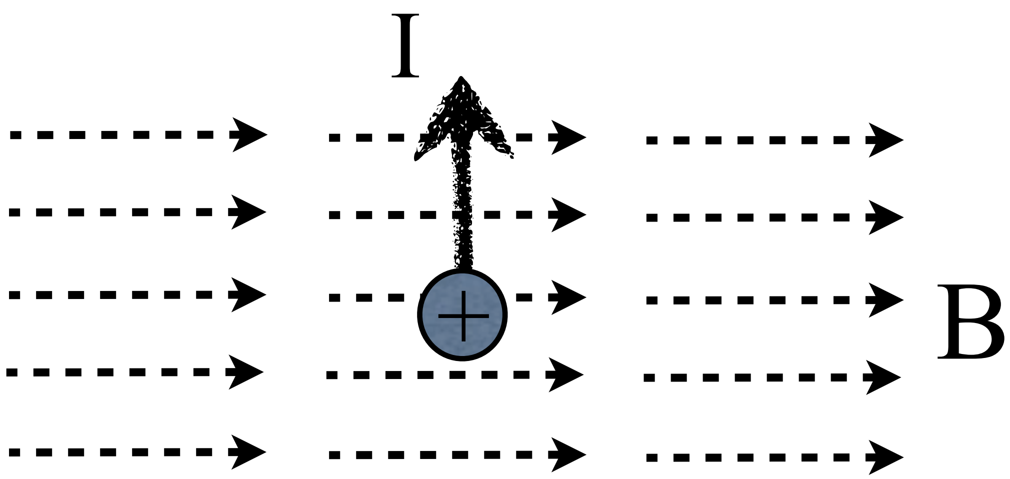
A straight long wire carries an electric current to the right. The current is placed in a uniform magnetic field directed into the screen. What is the direction of the magnetic force on the current?

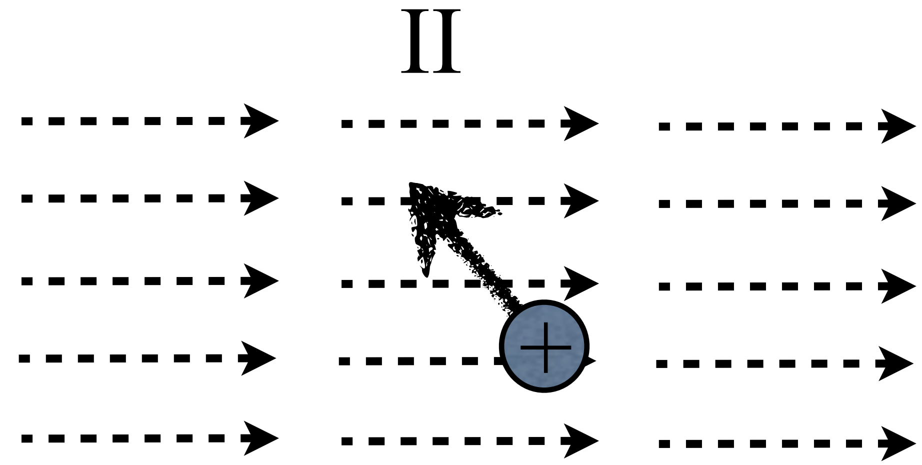
A. Left.
B. Right.
C. To the bottom of the screen.
D. To the top of the screen.
E. Out of the page.

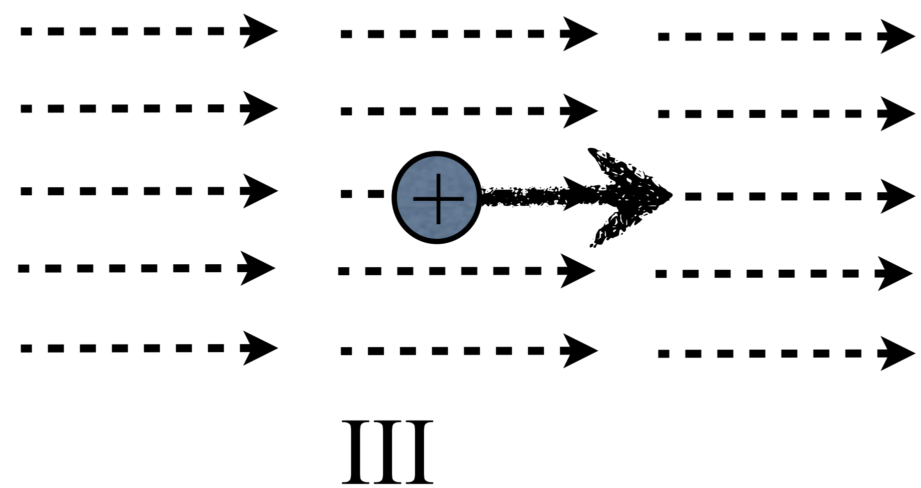


A straight long wire carries an electric current to the top of the page. The current is placed in a uniform magnetic field directed out of the page. What is the direction of the magnetic force on the current?

A. Left.
B. Right.
C. To the bottom of the screen.
D. To the top of the screen.
E. Out of the screen.







The figures represent positively charged particles moving in the same uniform magnetic field. The field is directed from left to right. All of the particles have the same charge and the same speed v. Rank these situations according to the magnitudes of the force exerted by the field on the moving charge, from greatest to least.

A. I = II = III

B. III > I > II

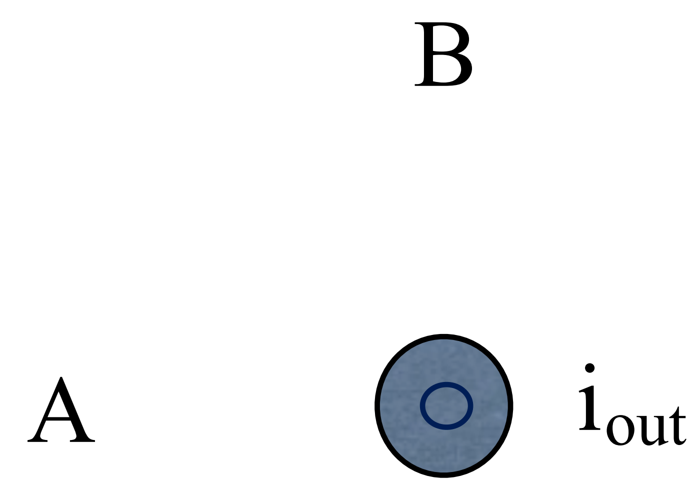
C. II > I > III

D. I > II > III

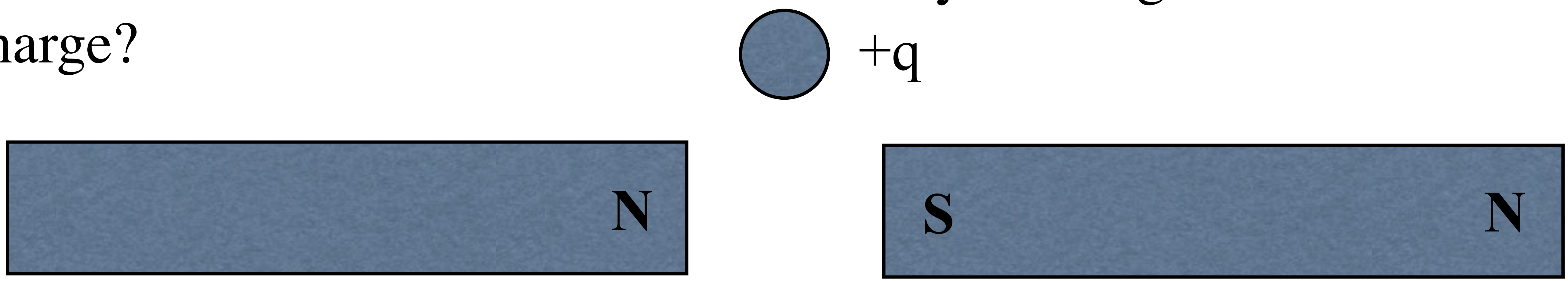
E. III > II > I

The diagram shows a wire with a large electric current i coming out of the paper. In what direction would the magnetic field be at positions A and B?

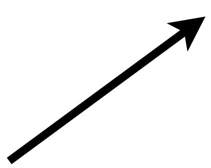
Position	A	B
A	↓	←
B	→	↓
C	↑	→
D	←	↑
E	None of these	



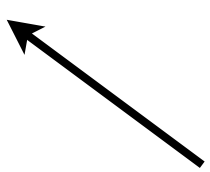
A positively charged particle +q is at rest in the plane between two fixed bar magnets, as shown. The magnet on the left is three times as strong as the magnet on the right. Which choice below best represents the resultant MAGNETIC force exerted by the magnets on the charge?



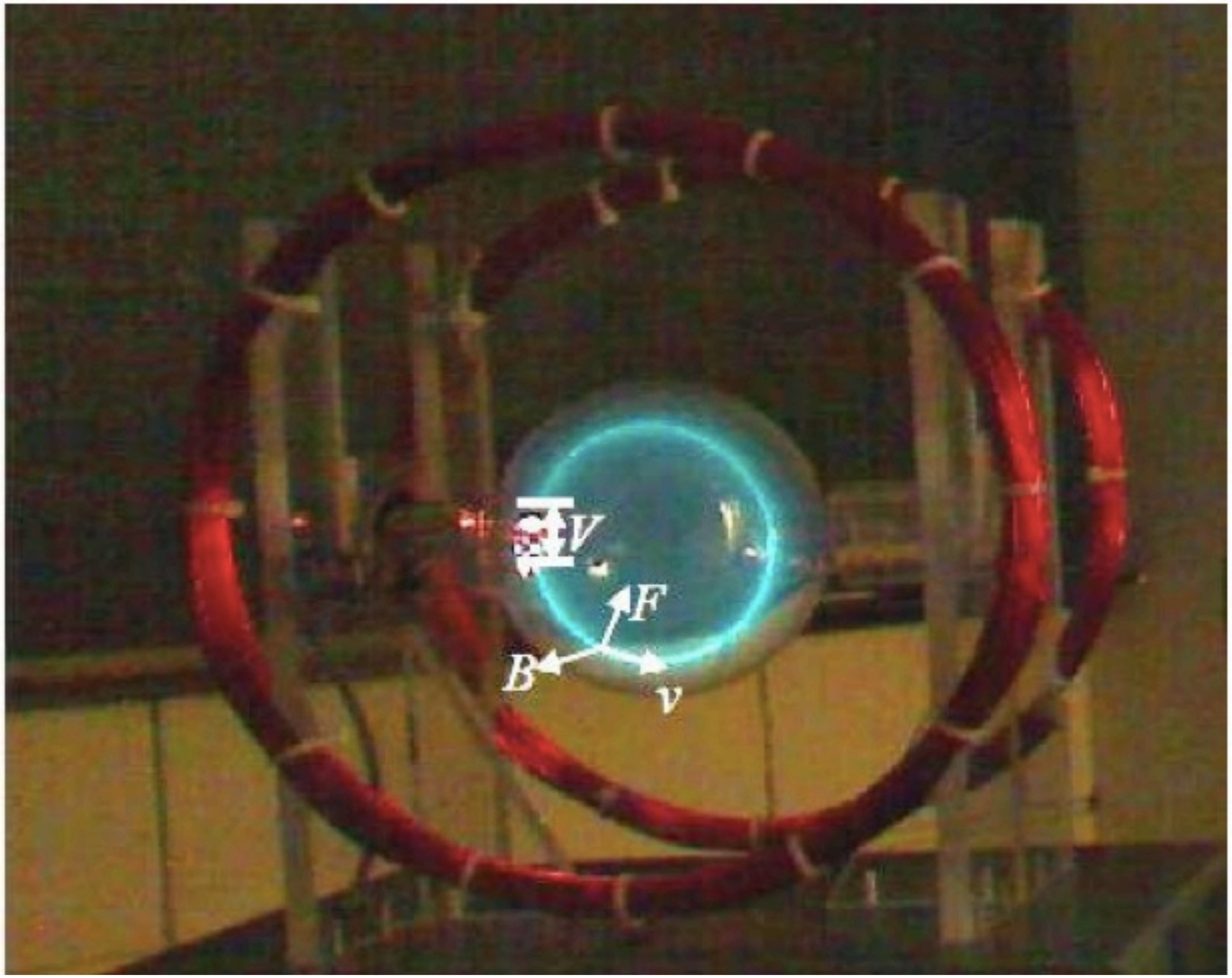
A) 

B) 

C) 

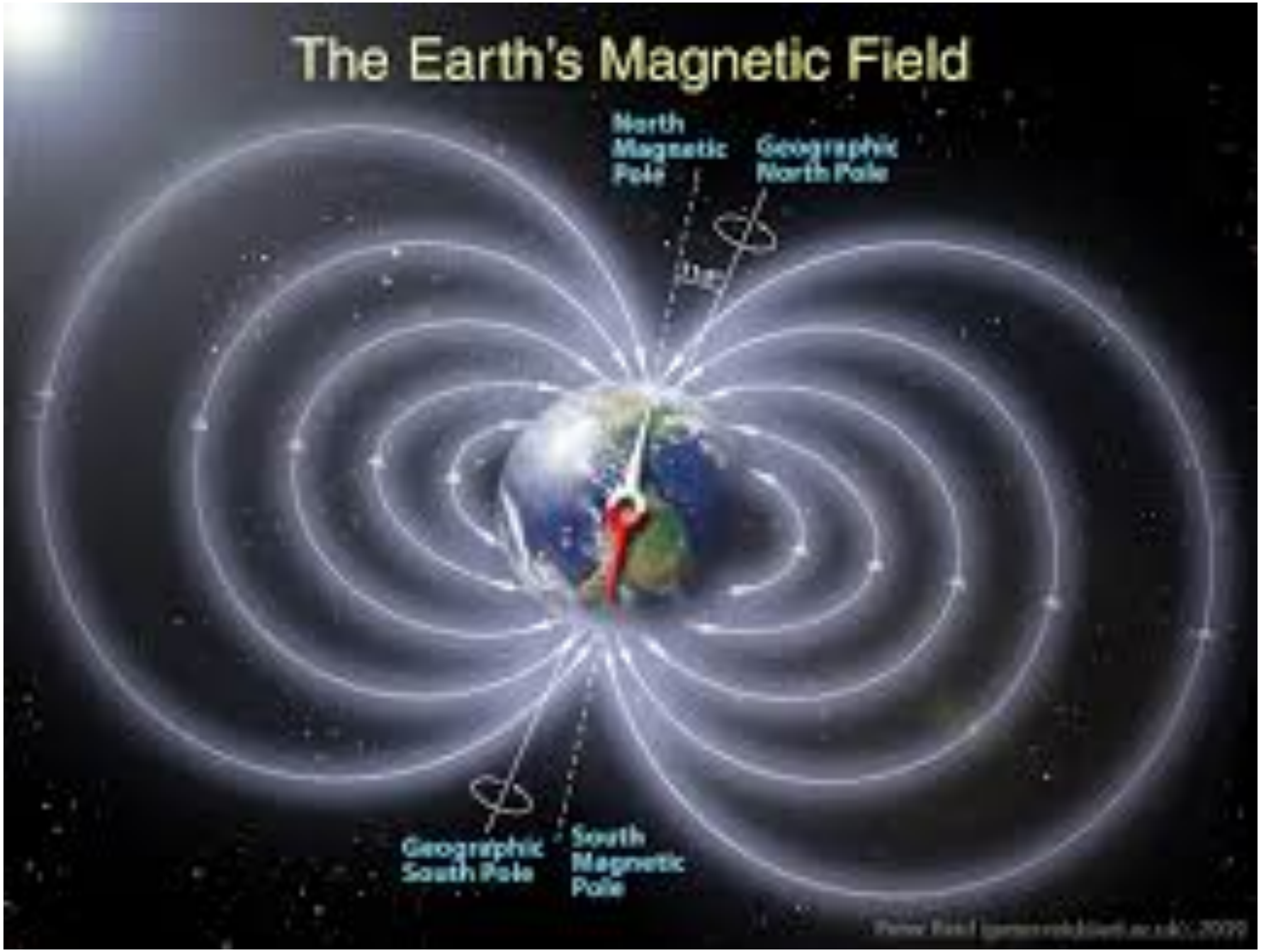
D) 

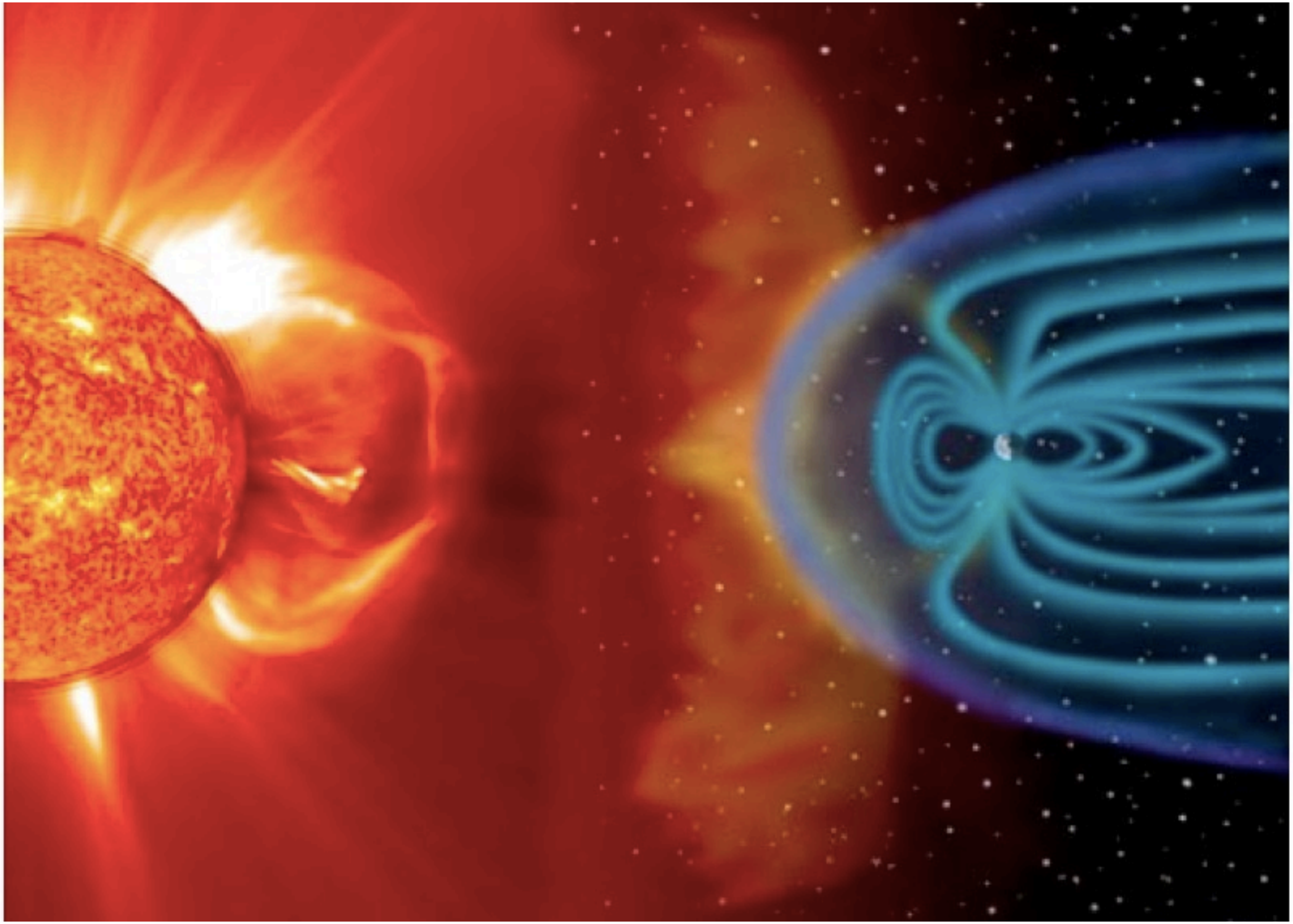
E) Zero

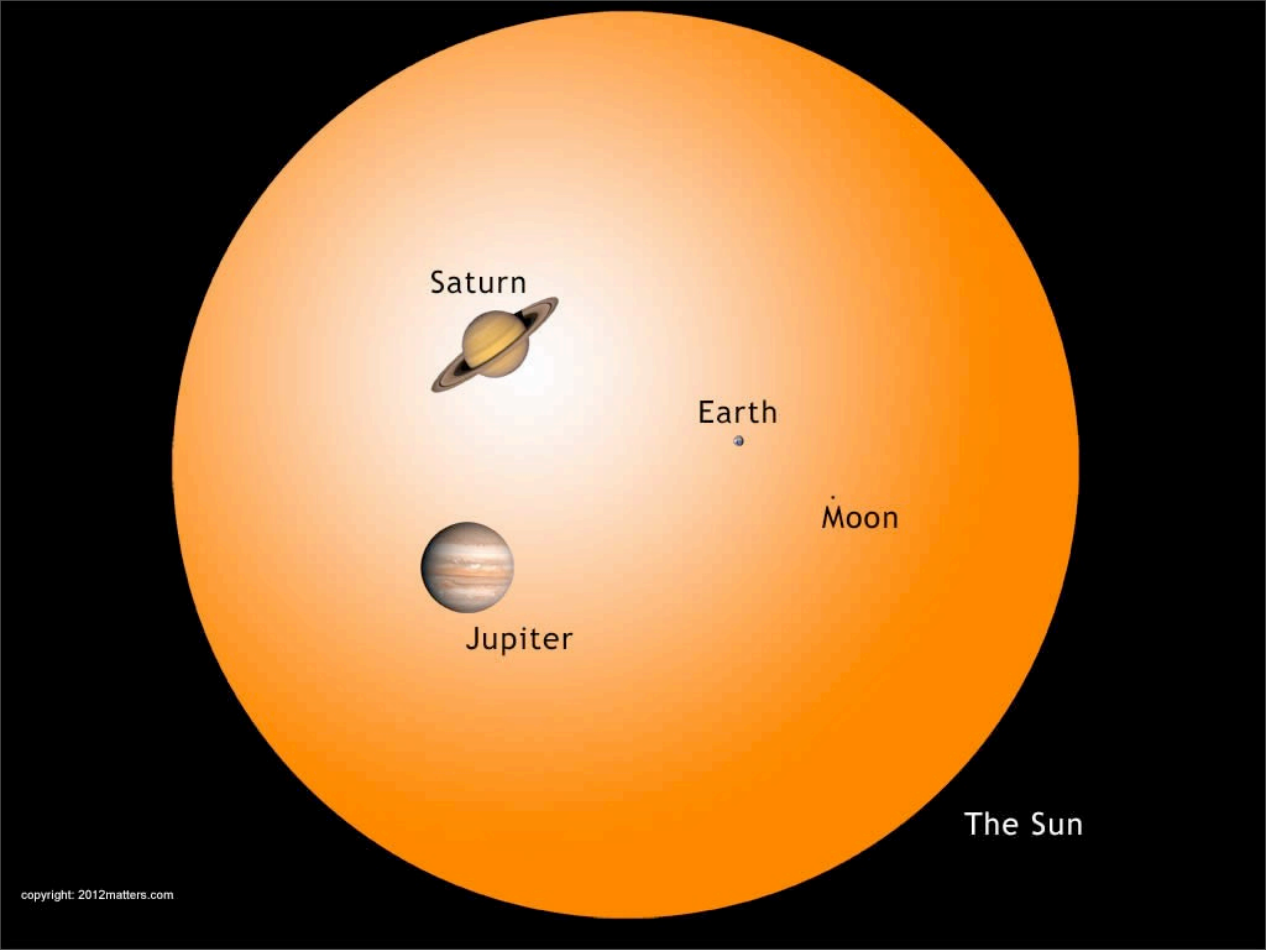


$$F = qvB$$

Notice all three vectors are perpendicular to one another


The Earth's Magnetic Field
North Magnetic Pole
Geographic North Pole
Geographic South Pole
South Magnetic Pole




Saturn
Earth
Moon
Jupiter
The Sun
copyright: 2012matters.com

Green is usually Oxygen and red usually Nitrogen
but these can vary

$$B = \frac{F}{qv}$$

1T = 1 (N/coulomb x metre/second) =

1 (N/metre x coulomb/second) =

1 (N/metre x Ampere) = 1 Tesla

(in the most fundamental units, 1 Tesla = 1 kg/(coulomb-second)

Some Approximate Magnetic Fields (in Tesla)

In interstellar space	10^{-10} T
At Earth's surface	10^{-4} T
Near a small bar magnet	10^{-2} T
Near a big electromagnet	1.5 T
At the surface of a neutron star	10^{8} T

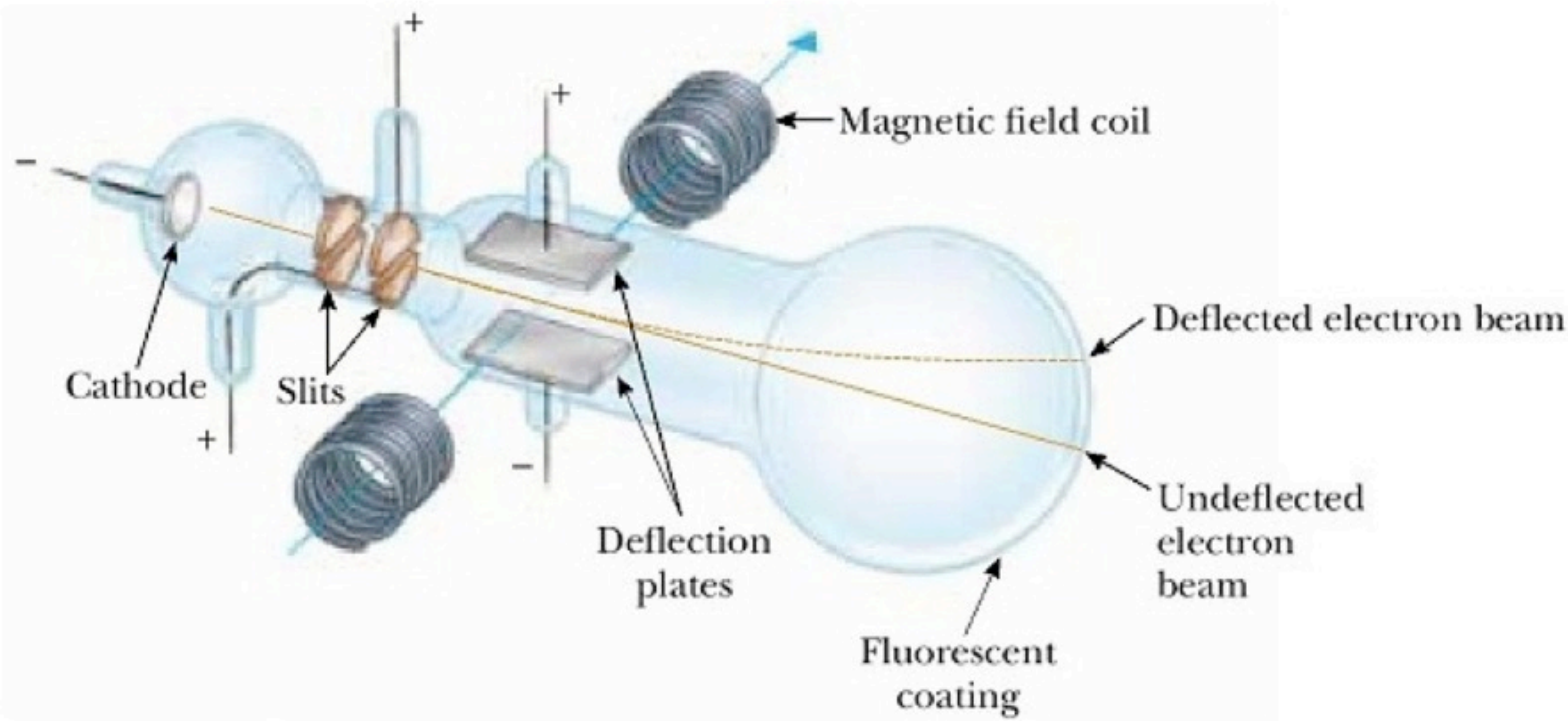


Figure 29.24 Thomson's apparatus for measuring e/m_e. Electrons are accelerated from the cathode, pass through two slits, and are deflected by both an electric field and a magnetic field (directed perpendicular to the electric field). The beam of electrons then strikes a fluorescent screen.