Magnetism

I. Magnetic Field
- units, poles
- **effect on charge**

II. Magnetic Force on Current
- parallel currents, motors

III. Sources of Magnetic Fields
- Ampere's Law
- solenoids

IV. Magnetic Induction
- Faraday's Law
- Lenz's Law

	The student will be able to:	HW:
1	Define and illustrate the basic properties of magnetic fields and permanent magnets: field lines, north and south poles, magnetic compasses, Earth's magnetic field.	✓ 1 – 4
2	Solve problems relating magnetic force to the motion of a charged particle through a magnetic field, such as that found in a mass spectrometer.	5 – 11
3	Solve problems involving forces on a current carrying wire in a magnetic field and torque on a current carrying loop of wire in a magnetic field.	12 – 18
5	State and apply relation between magnetic field and position for a long current carrying wire and solve related problems.	19 – 25
6	Qualitatively describe and apply properties of magnetic dipole fields generated by loops of current and model behavior of magnetic materials using domains, ferromagnetism, paramagnetism, and diamagnetism.	26 – 30
7	State and apply Faraday's Law and Lenz's Law and solve problems involving induced emf and magnetic flux.	31 – 38

Magnetic Force on Charges

A moving charged particle will experience a force in a magnetic field:

$$\vec{F}_m = q\vec{v} \times \vec{B}$$

F = force on the particle
q = charge of the particle
v = velocity
B = magnetic field

Magnetic Force on Charges

A moving charged particle will experience a force in a magnetic field:

$$\left|\vec{\mathrm{F}}_m\right| = \left|qvB\sin\theta\right|$$

$$F_M = qv_\wedge B = qvB_\wedge$$

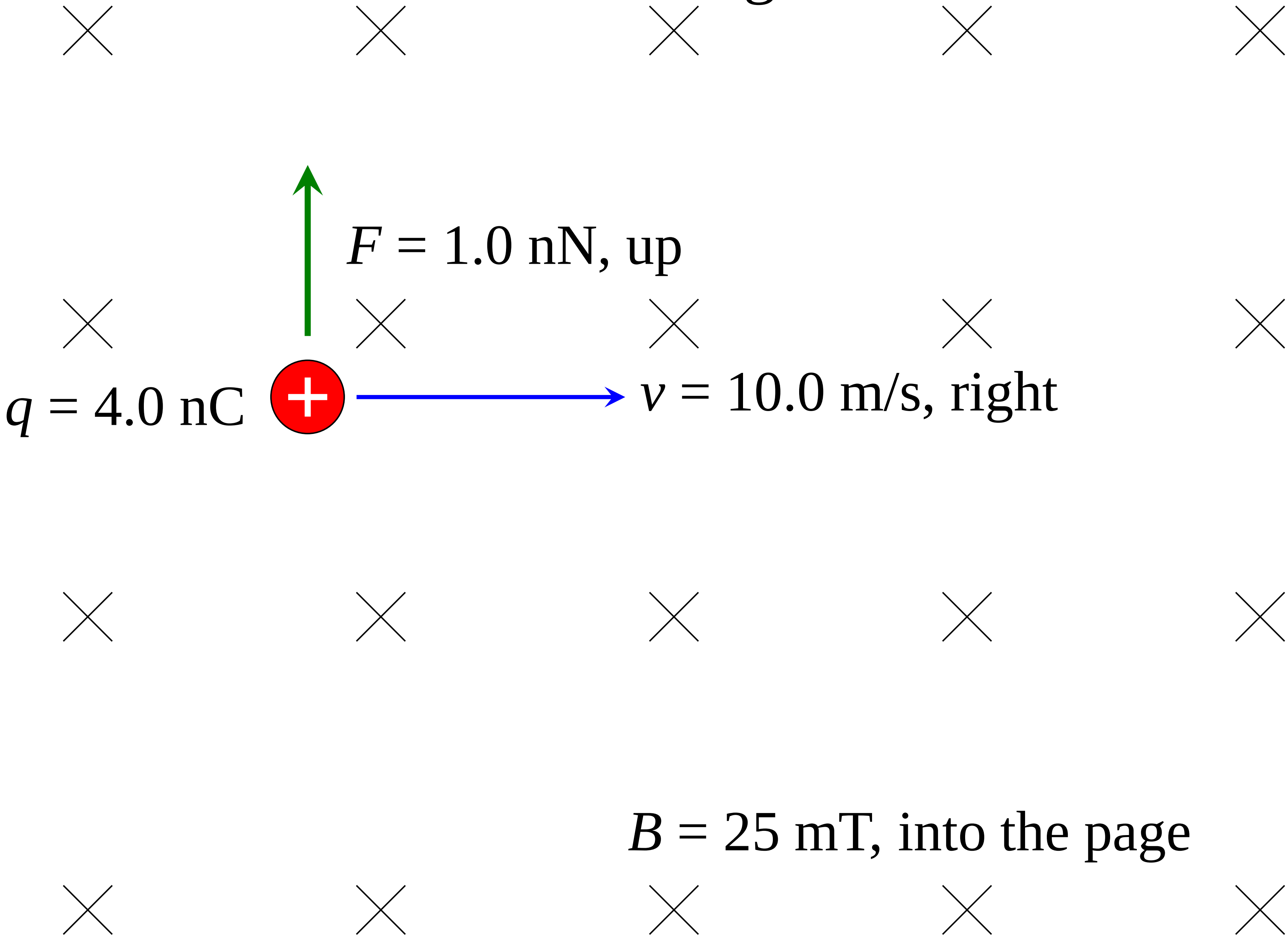
F = force on the particle

q = charge of the particle

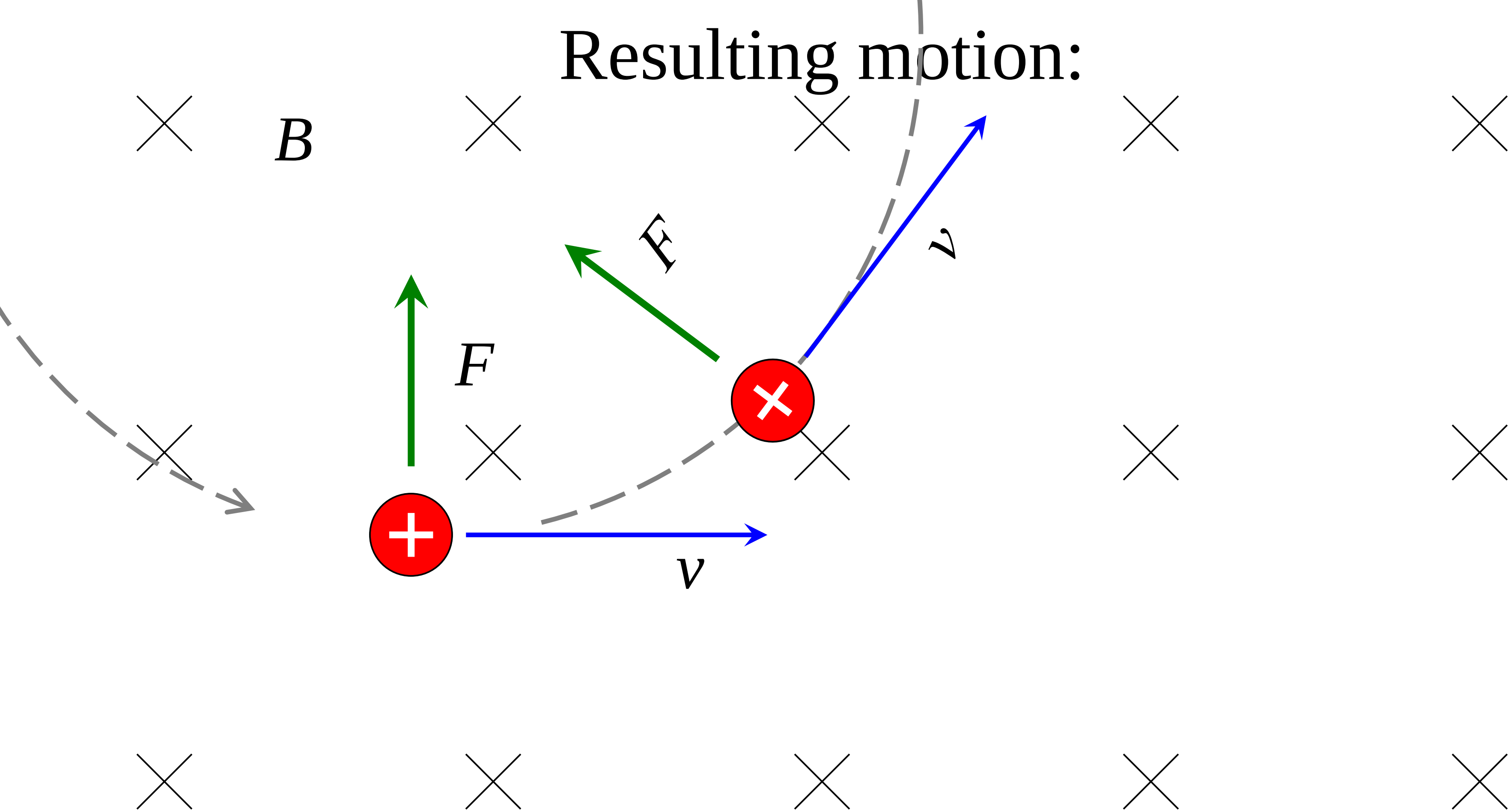
v = velocity

B = magnetic field

Determine the magnetic force:

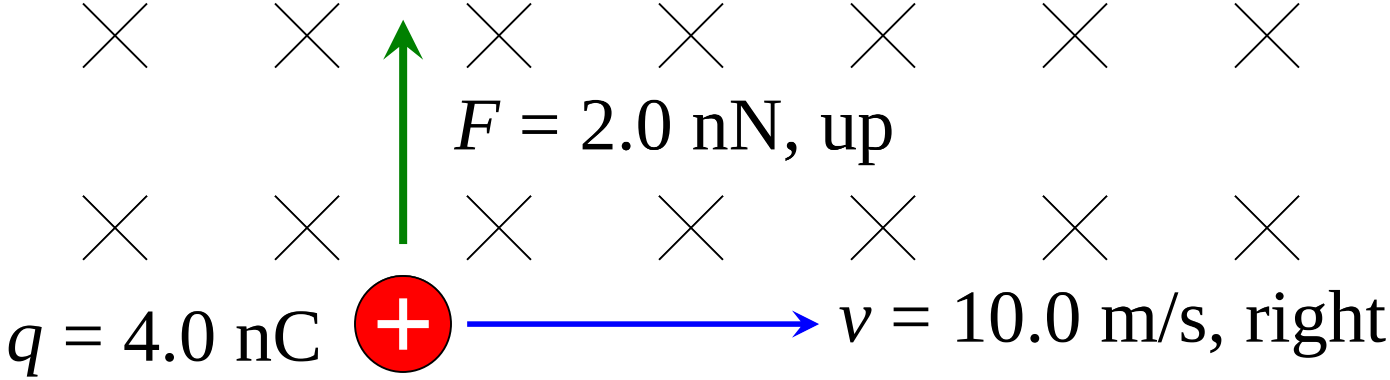


Resulting motion:



A moving charged particle has circular motion at constant speed in a uniform magnetic field!
The force is always perpendicular to the velocity.

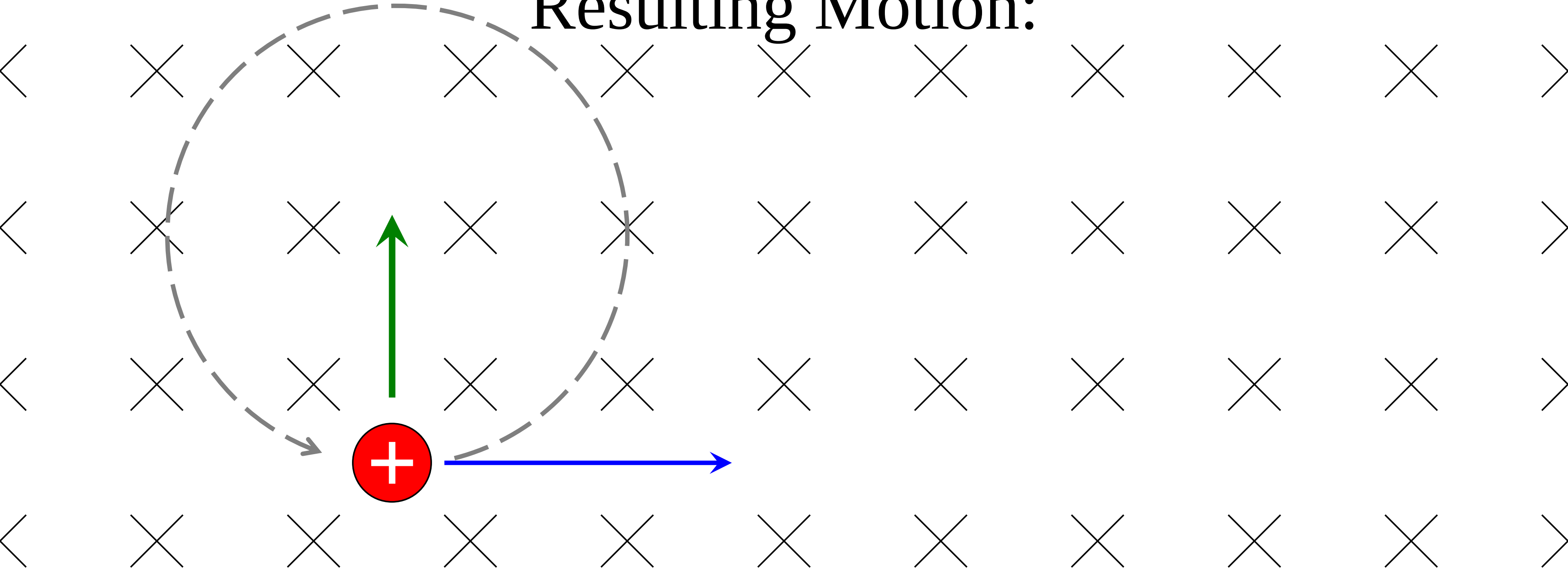
Determine the magnetic force:



Same charge, double the field, what will be different?

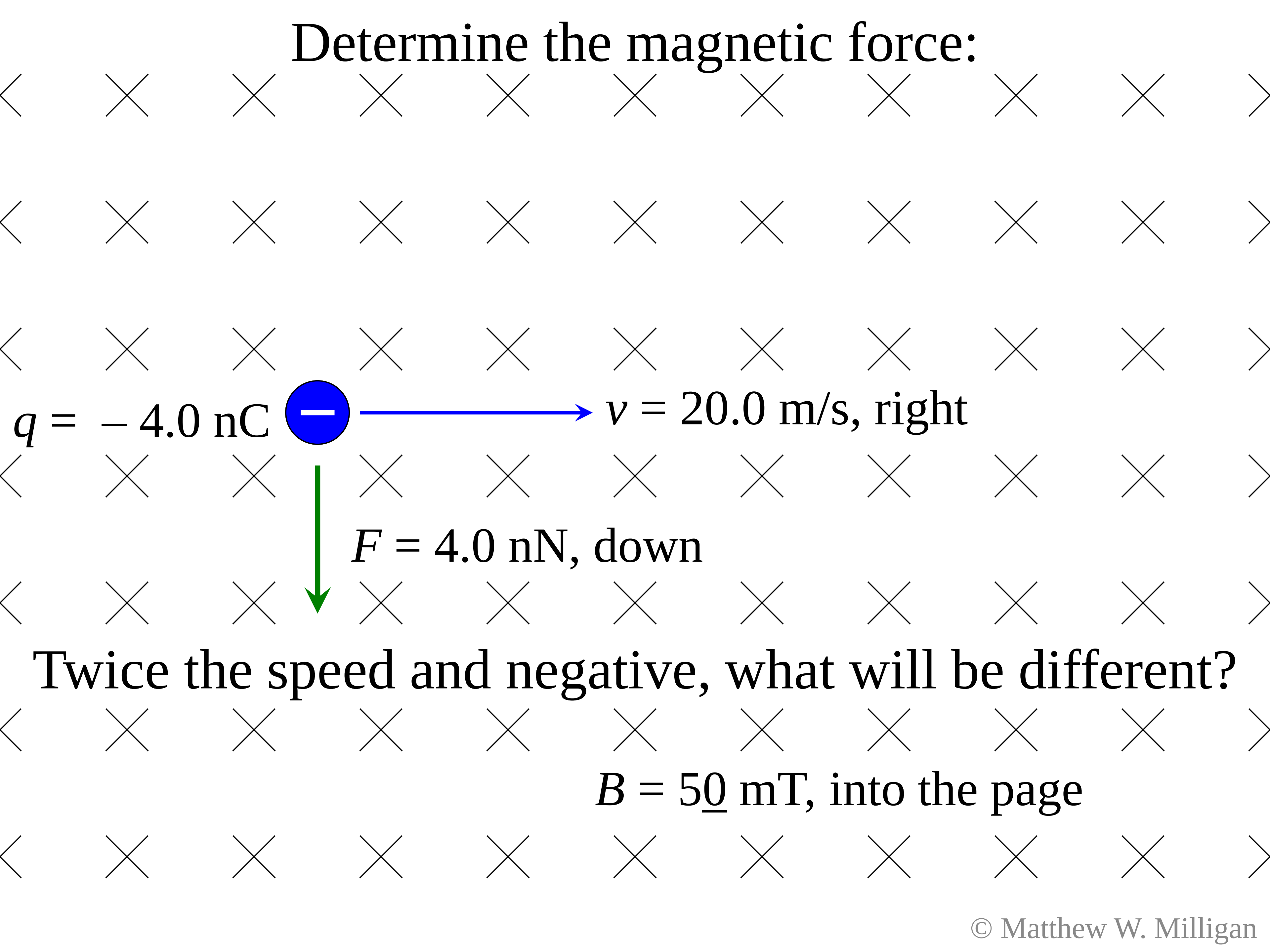
B = 5<u>0</u> mT, into the page

Resulting Motion:



Because the field is doubled twice as much force acts and causes greater acceleration and thus a smaller circle. Speed is unaffected!

B = 50 mT, into the page


Determine the magnetic force:
q = – 4.0 nC
v = 20.0 m/s, right
F = 4.0 nN, down
Twice the speed and negative, what will be different?
B = 50 mT, into the page
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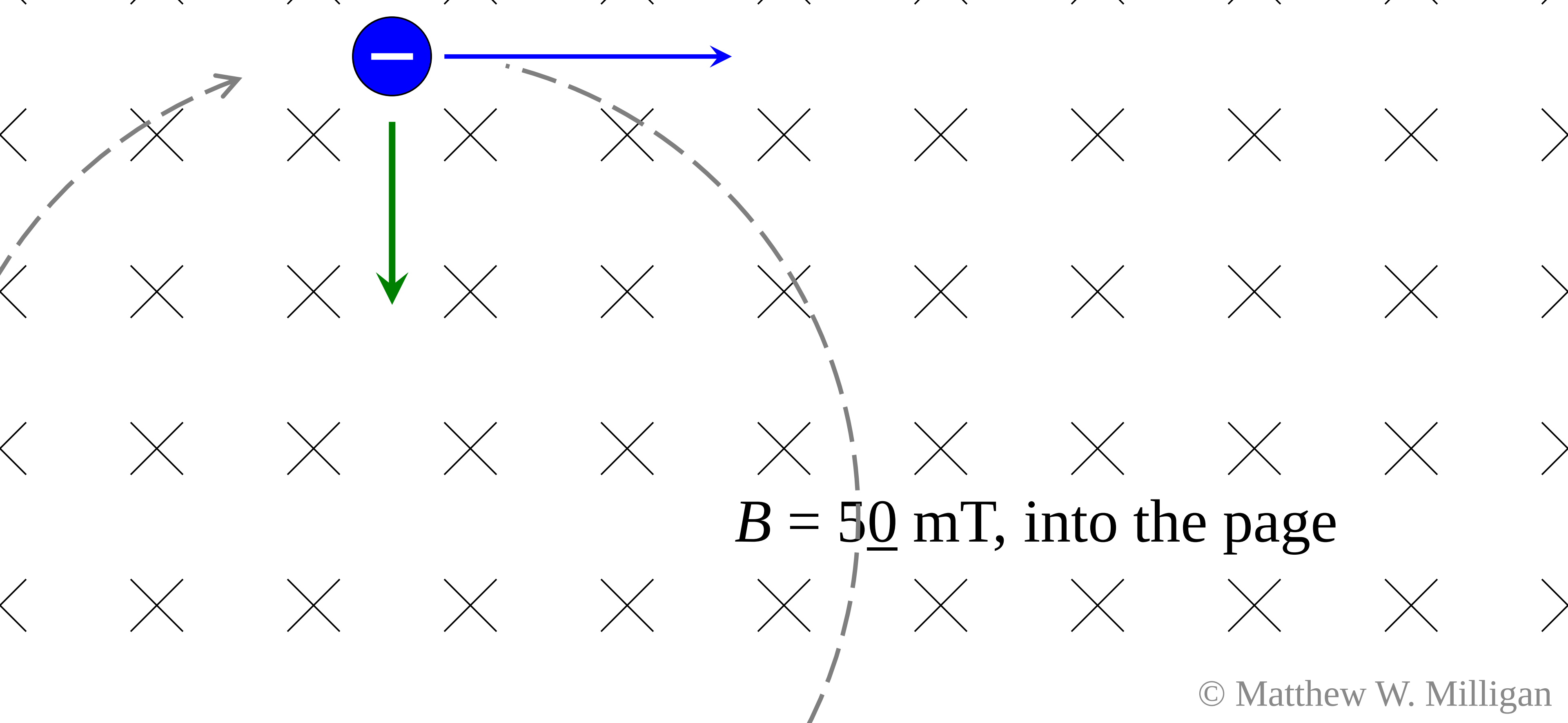
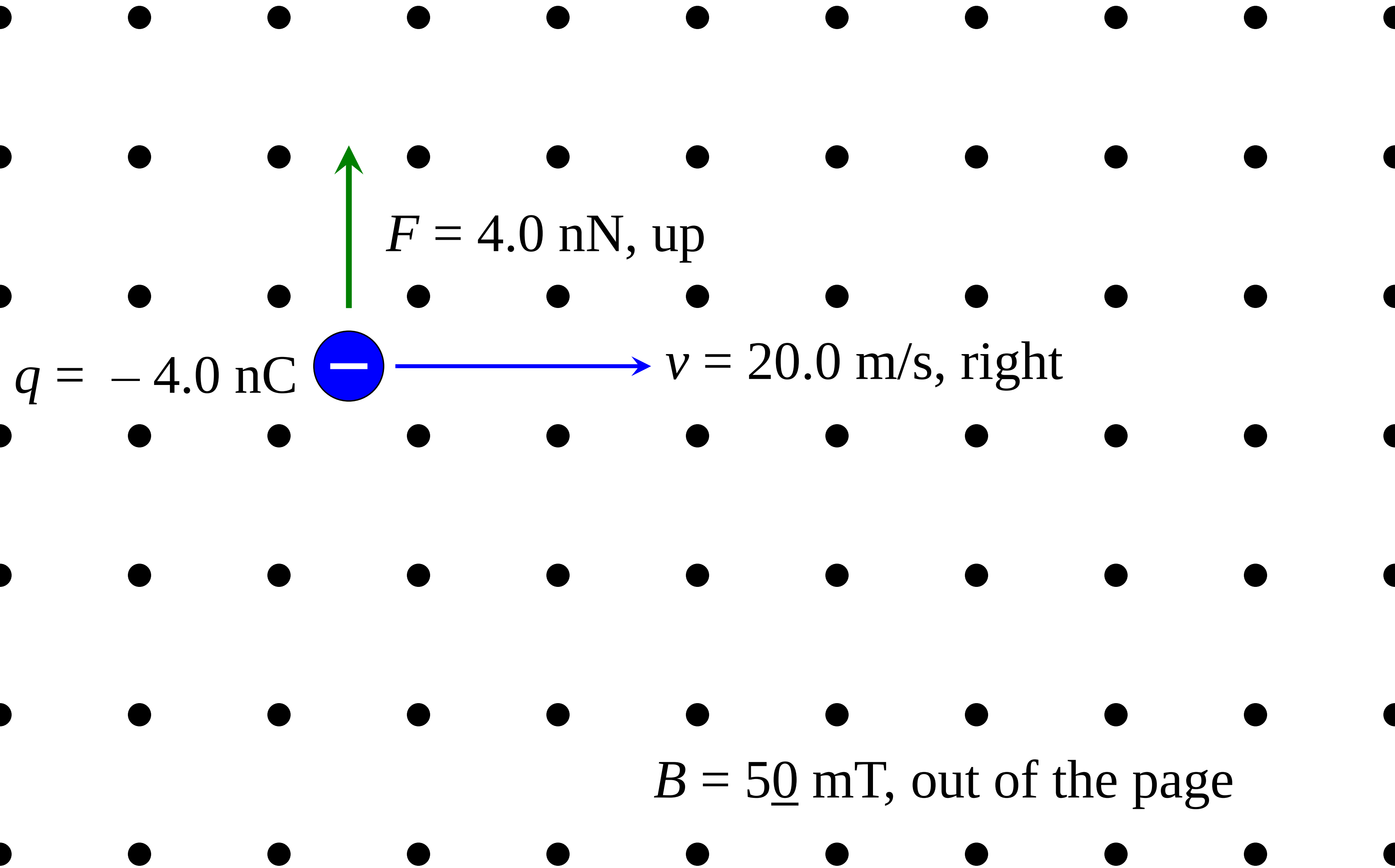
Resulting Motion:

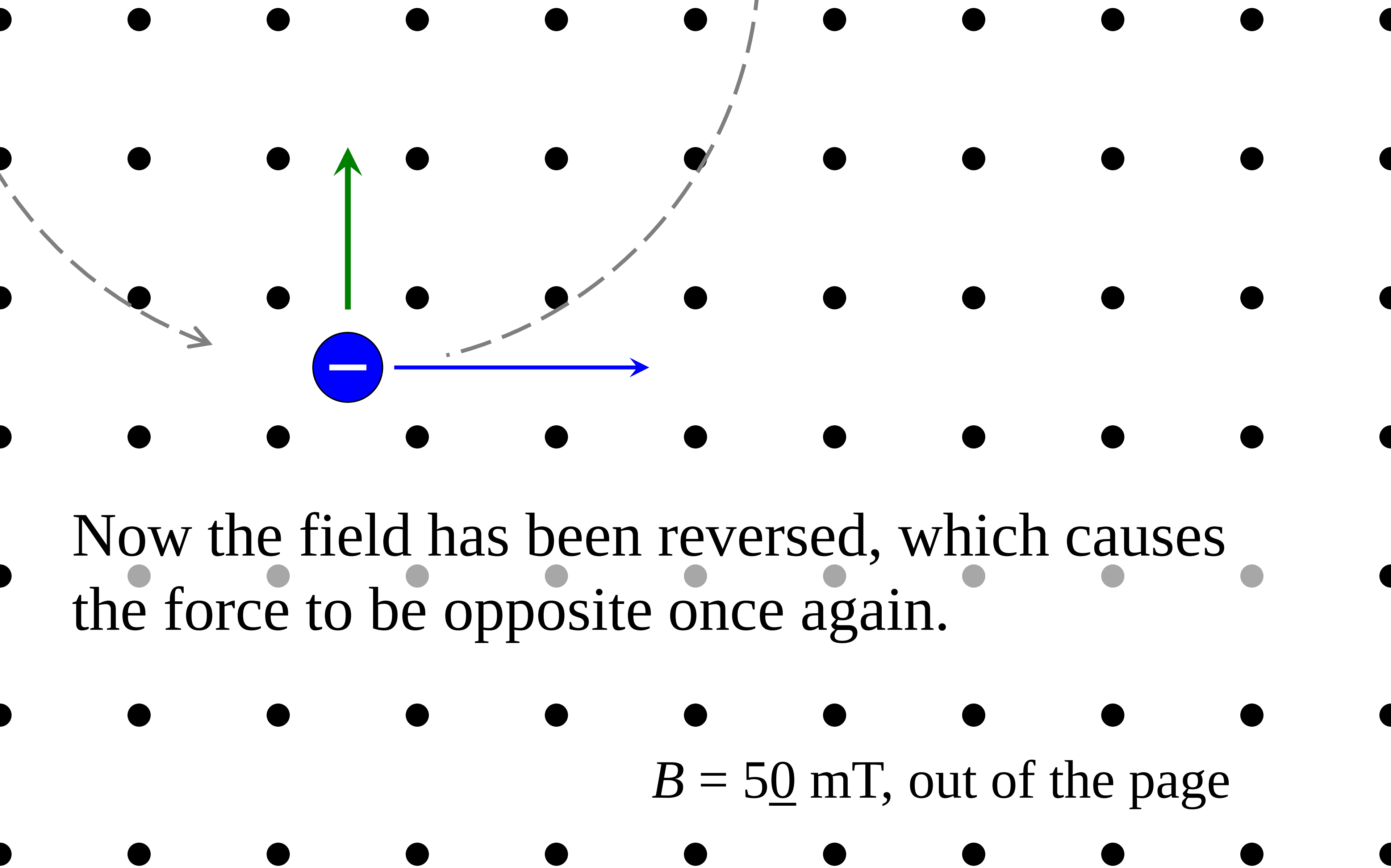
The force is same but in the opposite direction for a negative charge. Because it is moving faster the circle is larger in spite of the same acceleration.



Determine the magnetic force:



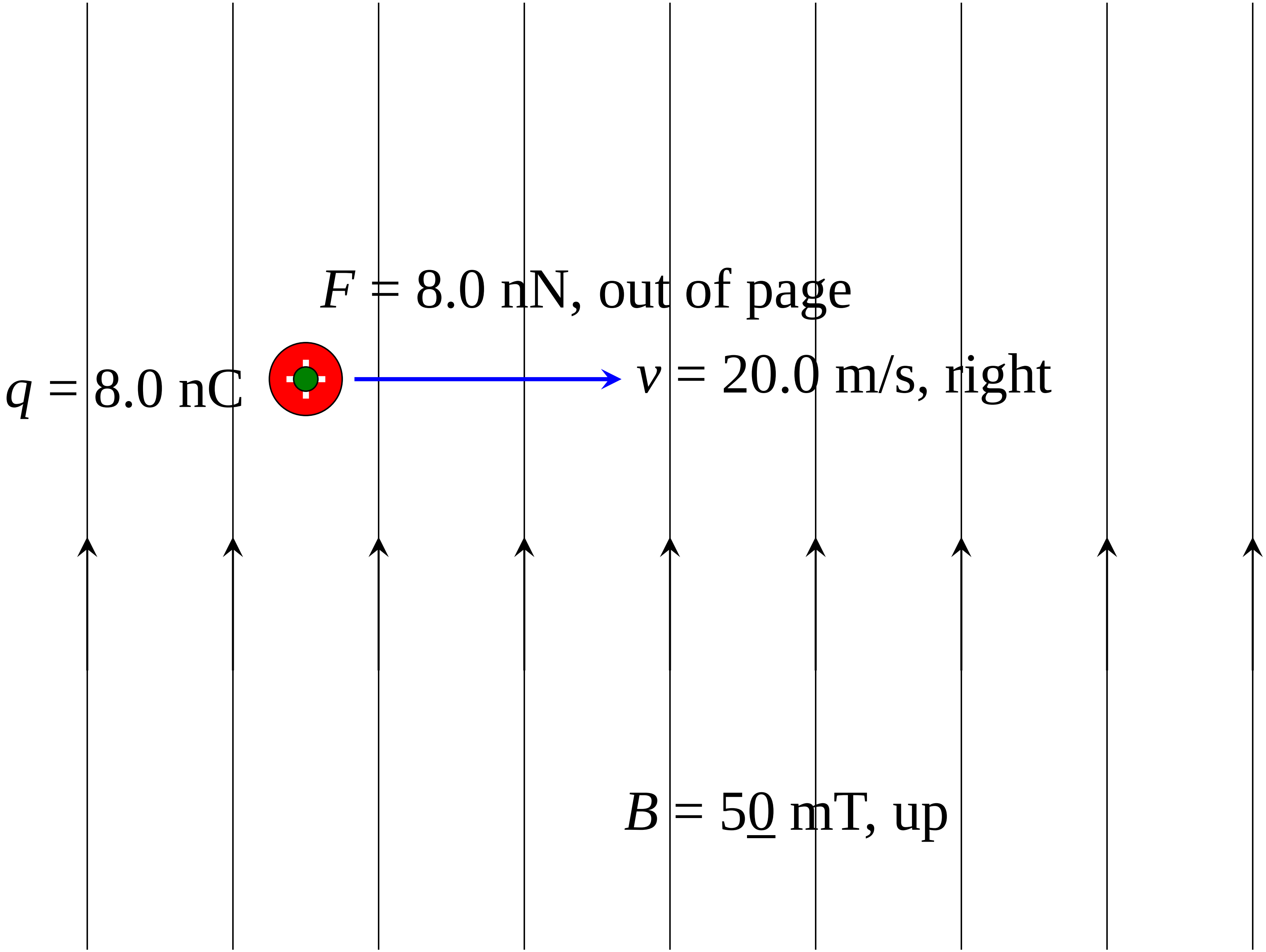
Resulting Motion:



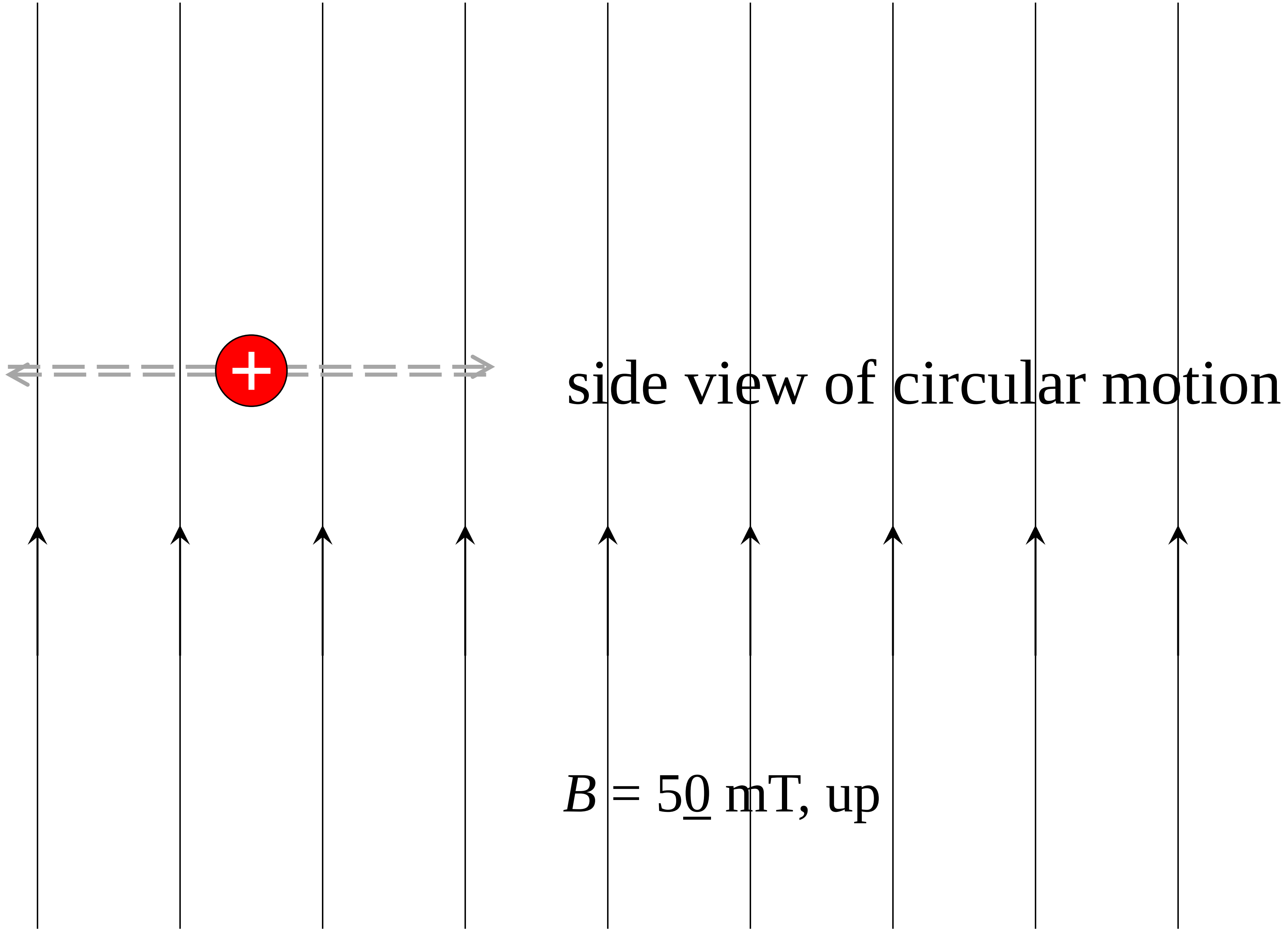
Now the field has been reversed, which causes the force to be opposite once again.

B = 5<u>0</u> mT, out of the page

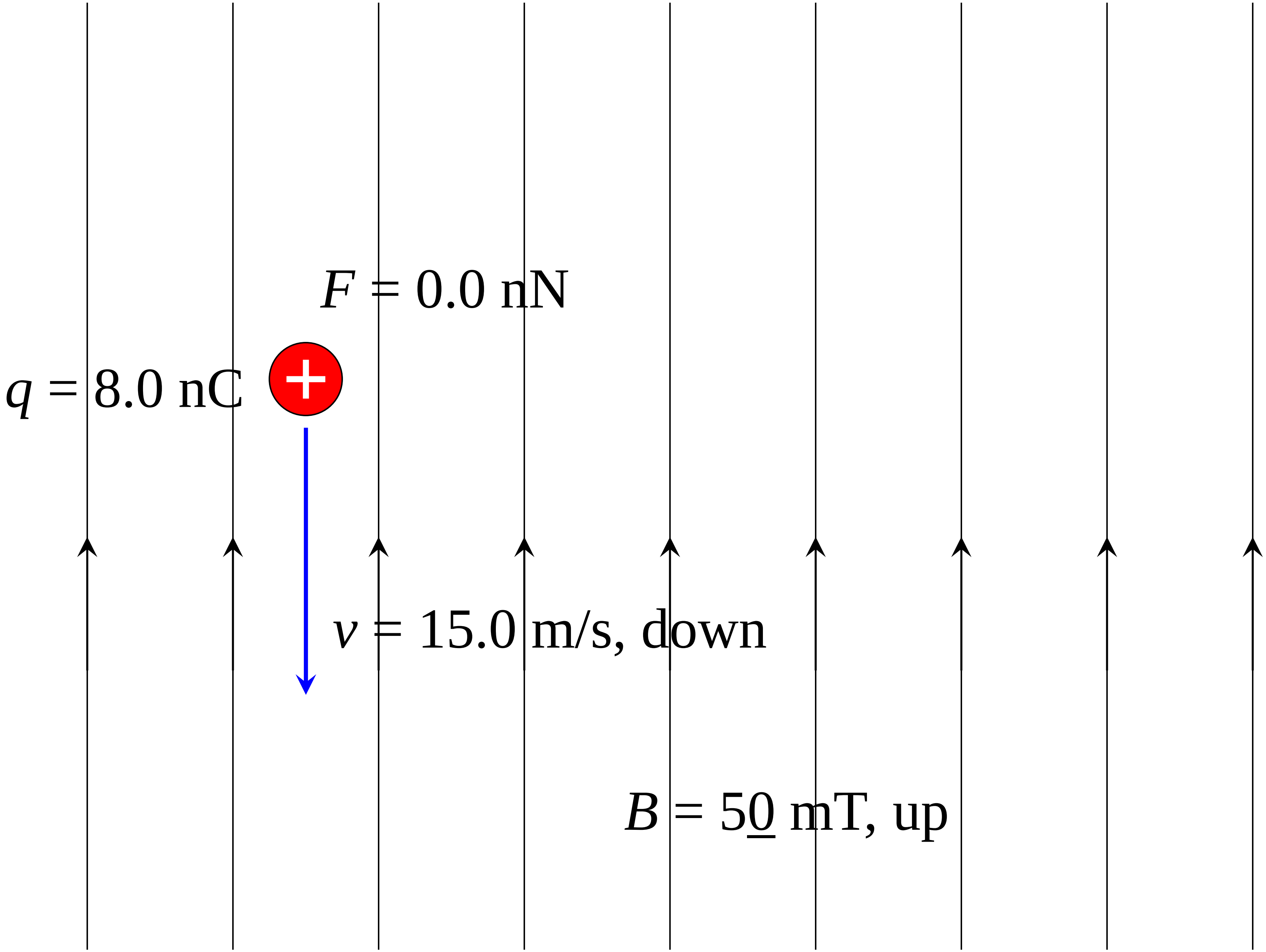
Determine the magnetic force:



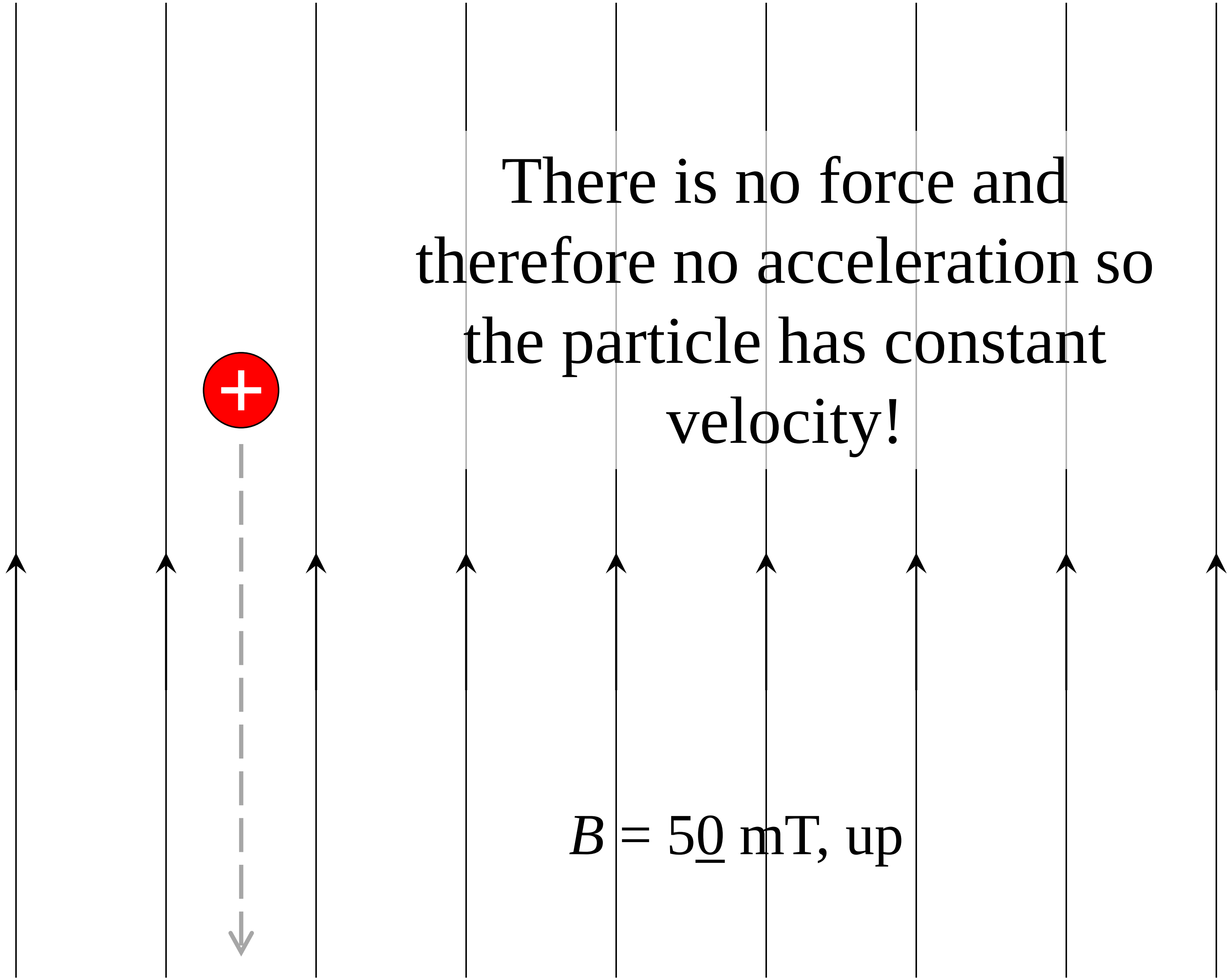
Resulting Motion:



Determine the magnetic force:

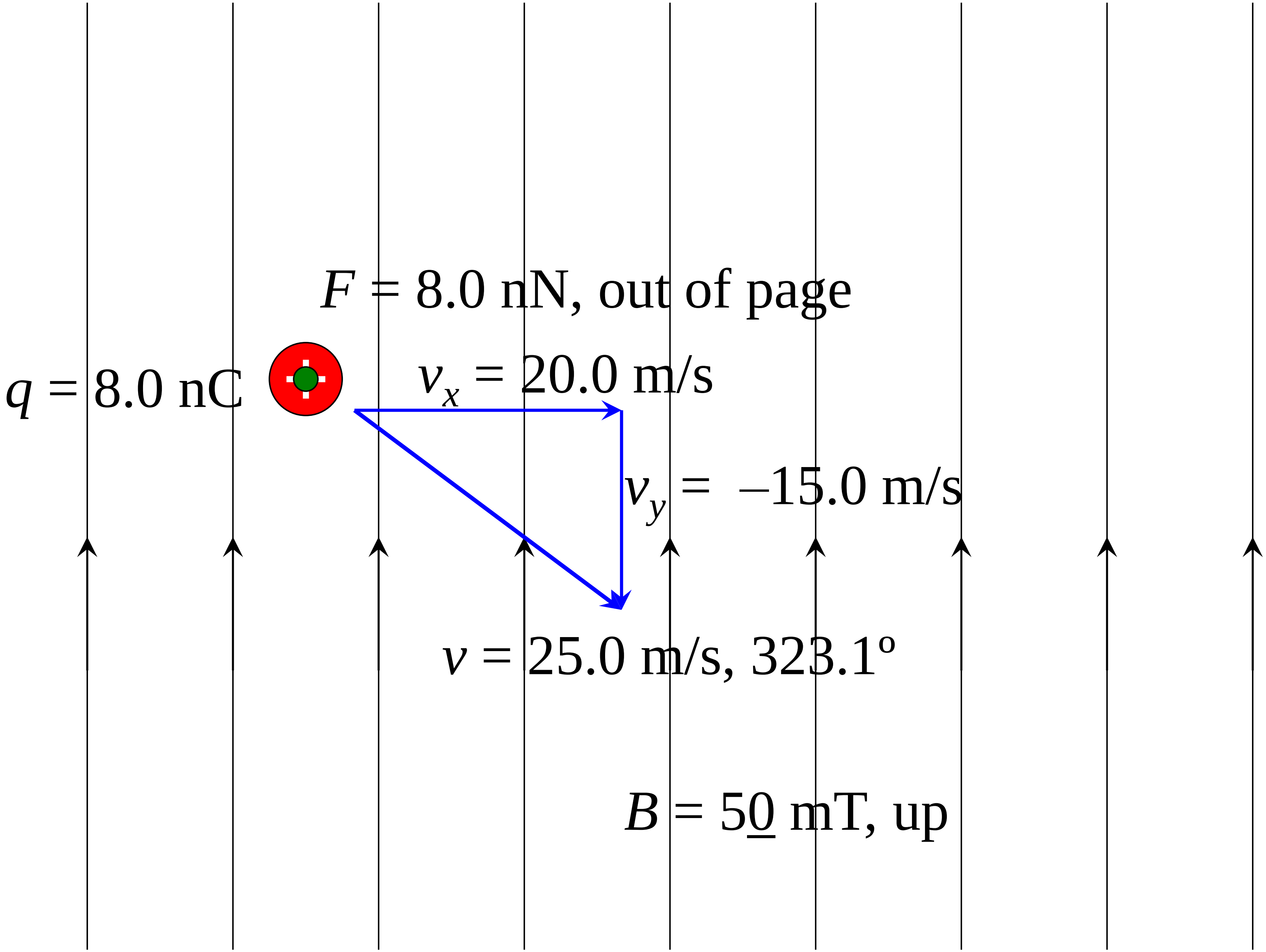


Resulting Motion:

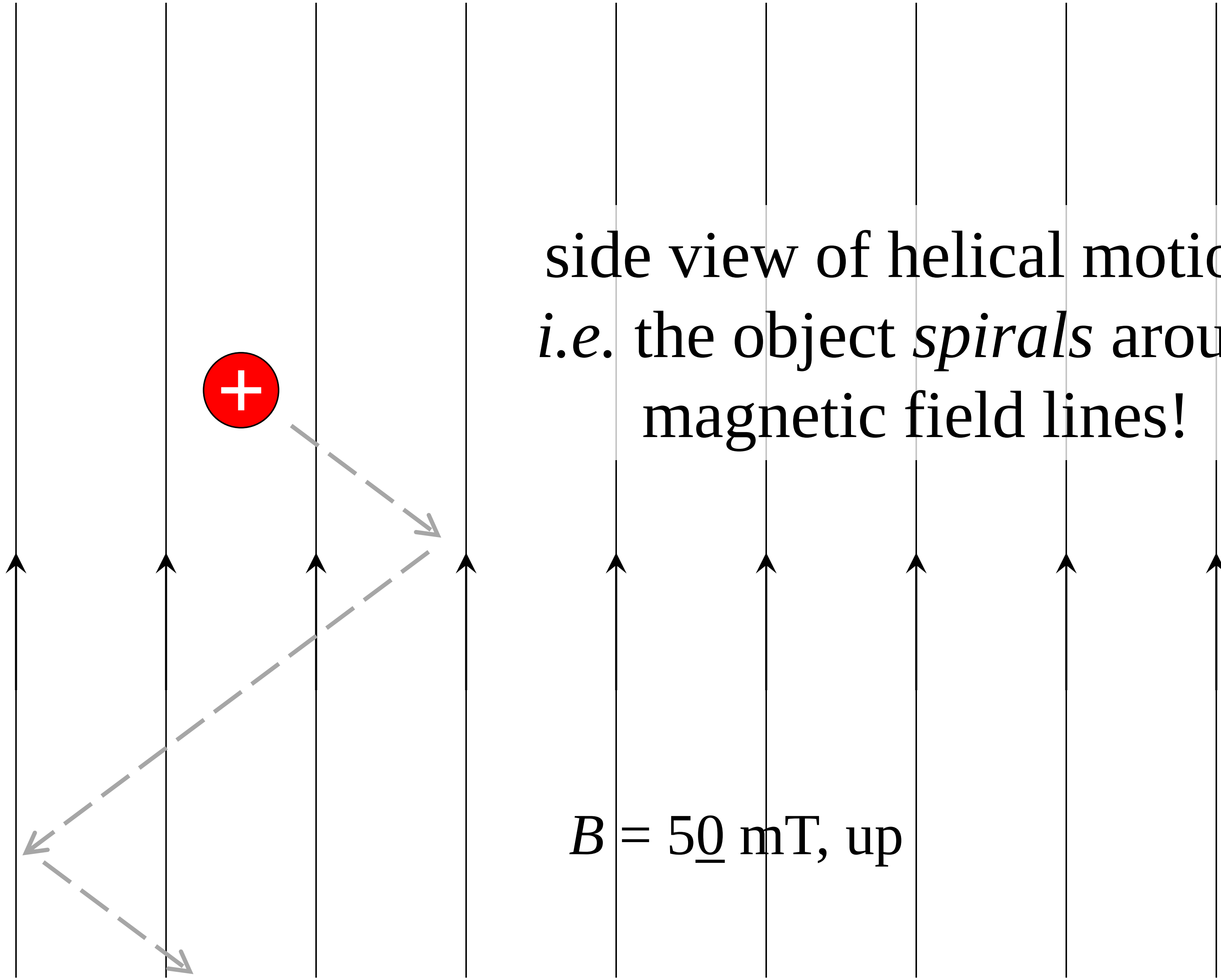


There is no force and therefore no acceleration so the particle has constant velocity!

Determine the magnetic force:



Resulting Motion:



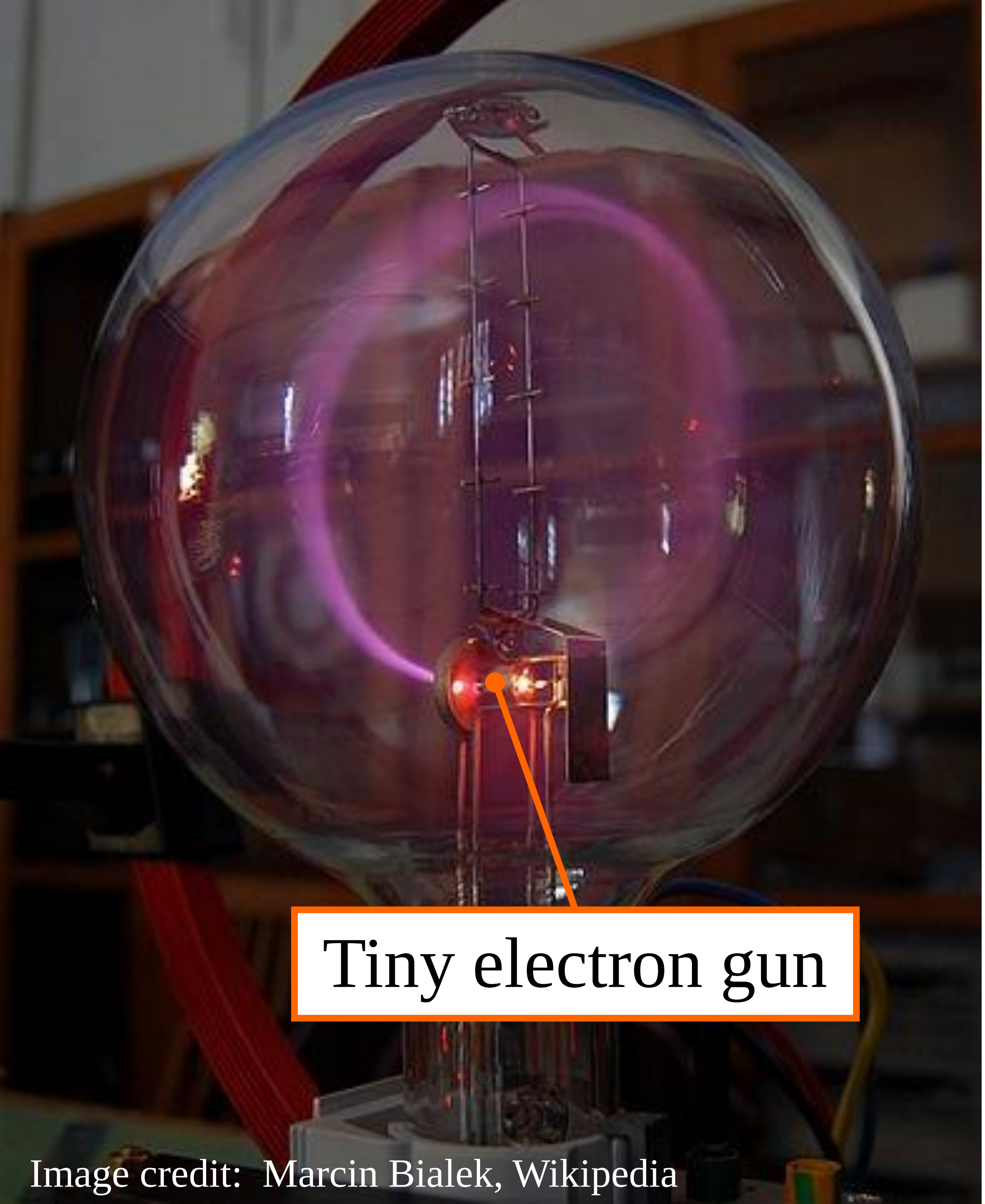
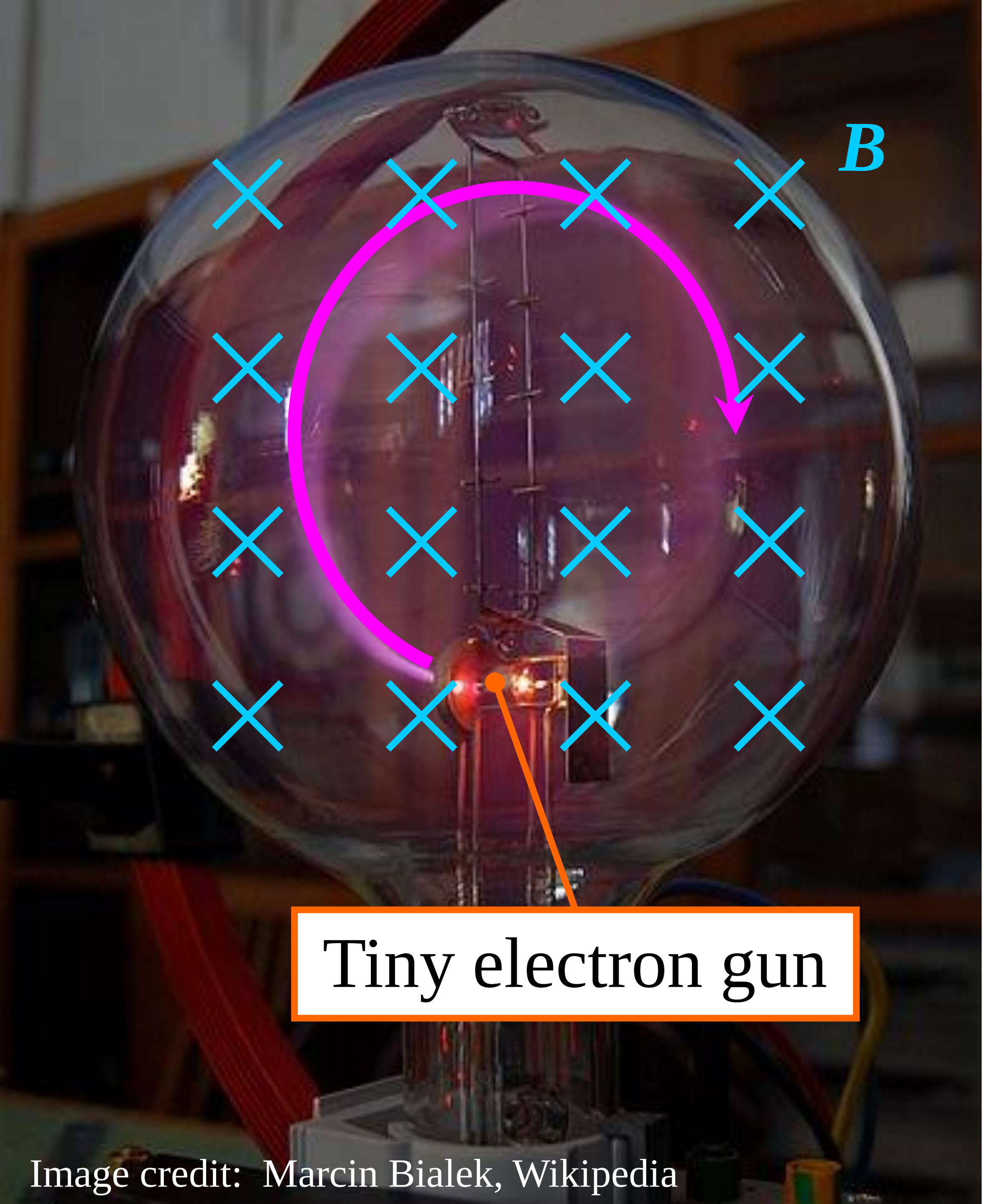


Image credit: Marcin Bialek, Wikipedia

Electrons are responsible for the glowing circle!

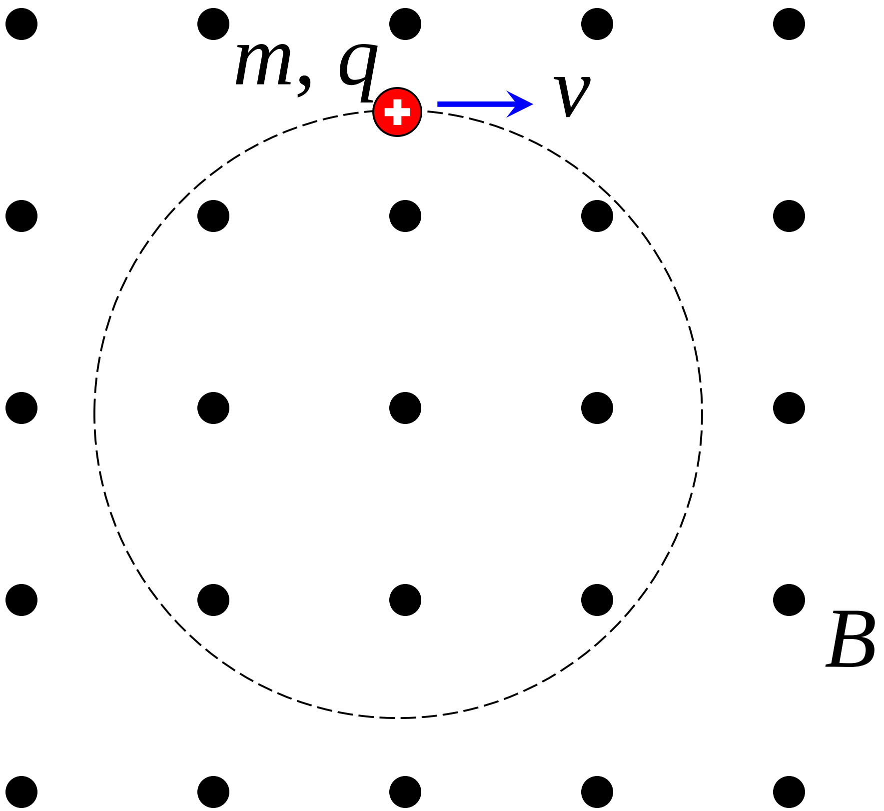
In what direction must the magnetic field point to cause the electrons to circle clockwise like this?



Electrons are responsible for the glowing circle!

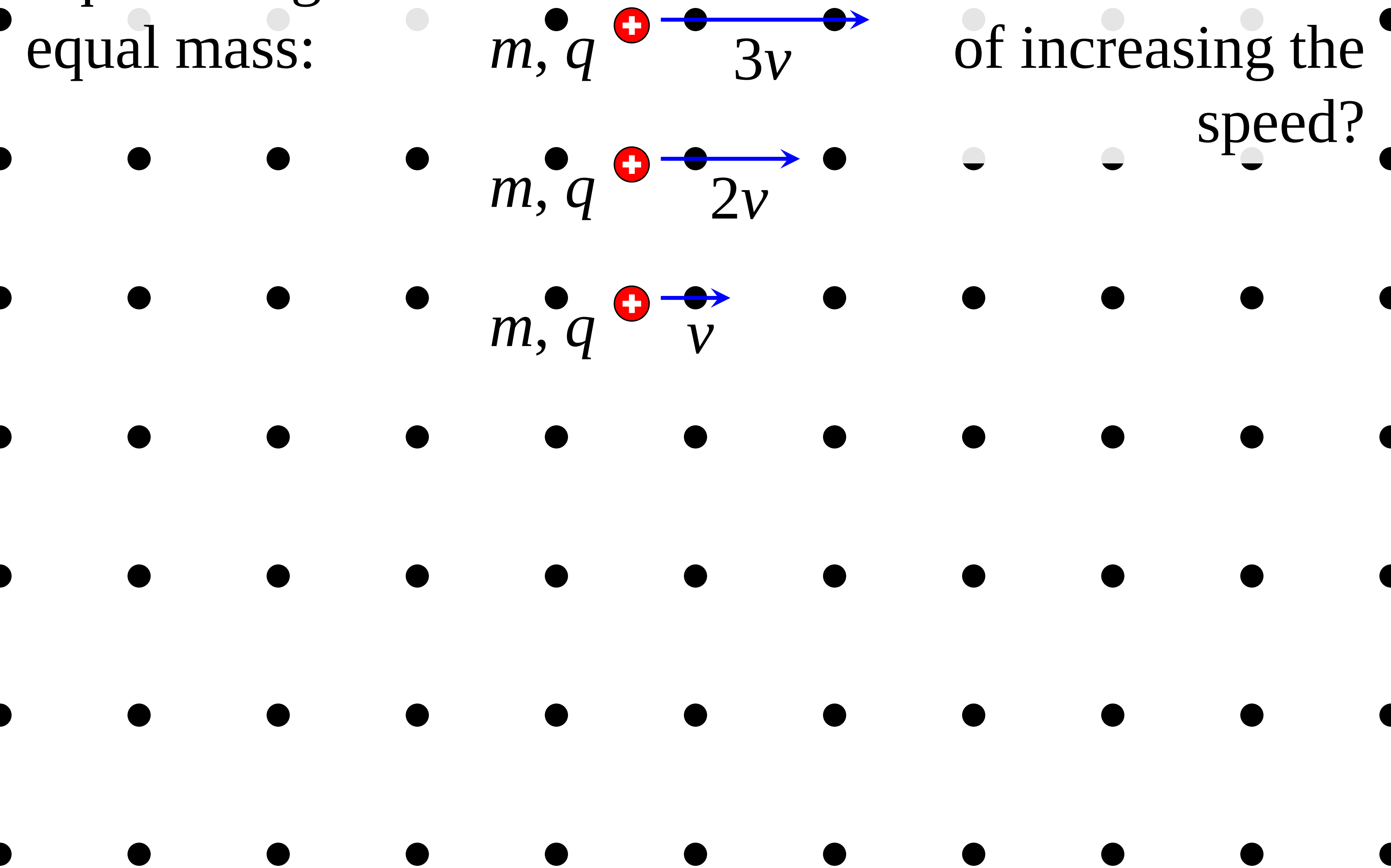
The magnetic field is perpendicular to the circle and away from our view or “into the page”.

A particle of mass *m* and charge *q* undergoes circular motion at speed *v* in a uniform magnetic field *B*. Determine the radius and period of this motion.



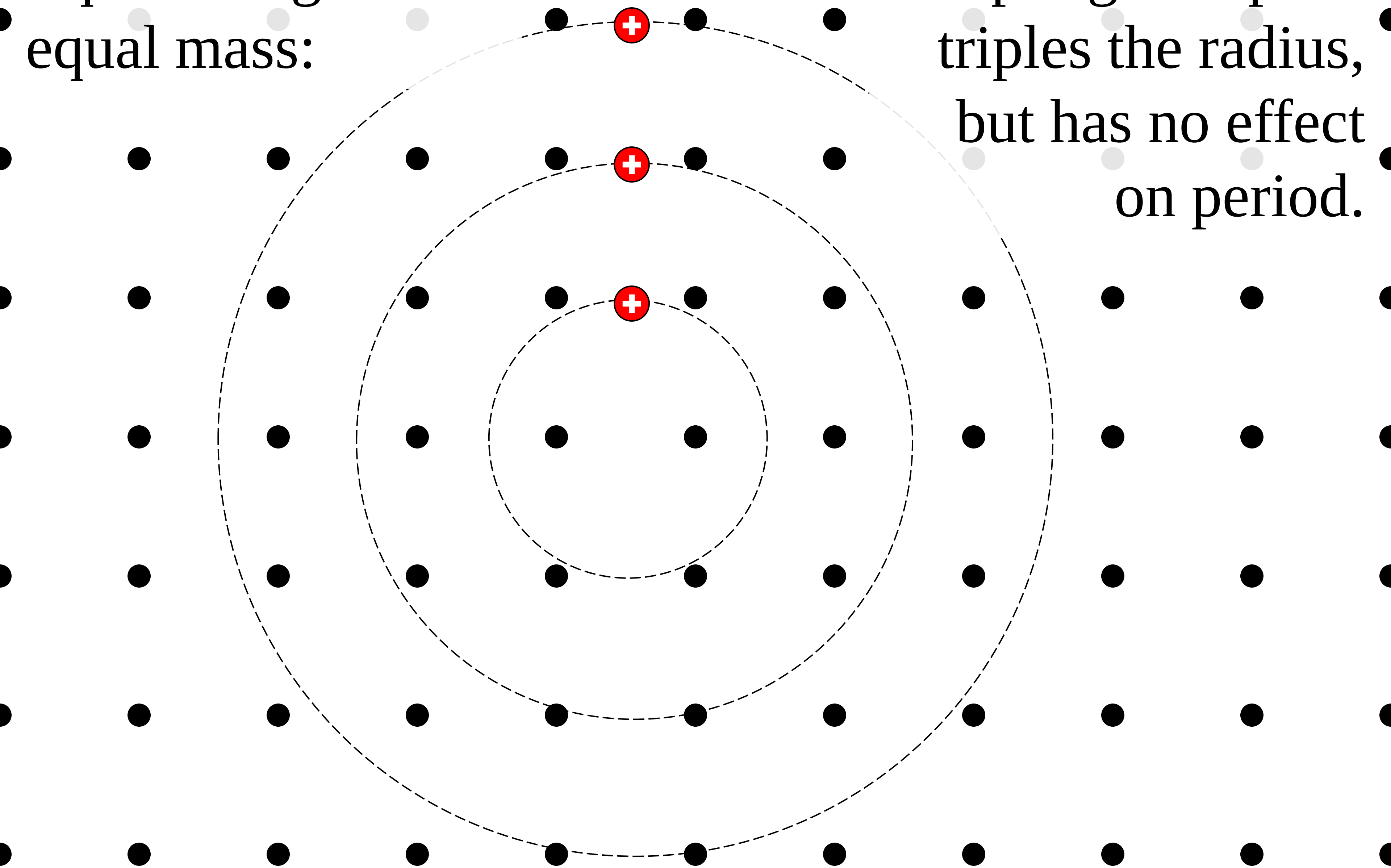
Equal charge and equal mass:

What is the effect of increasing the speed?



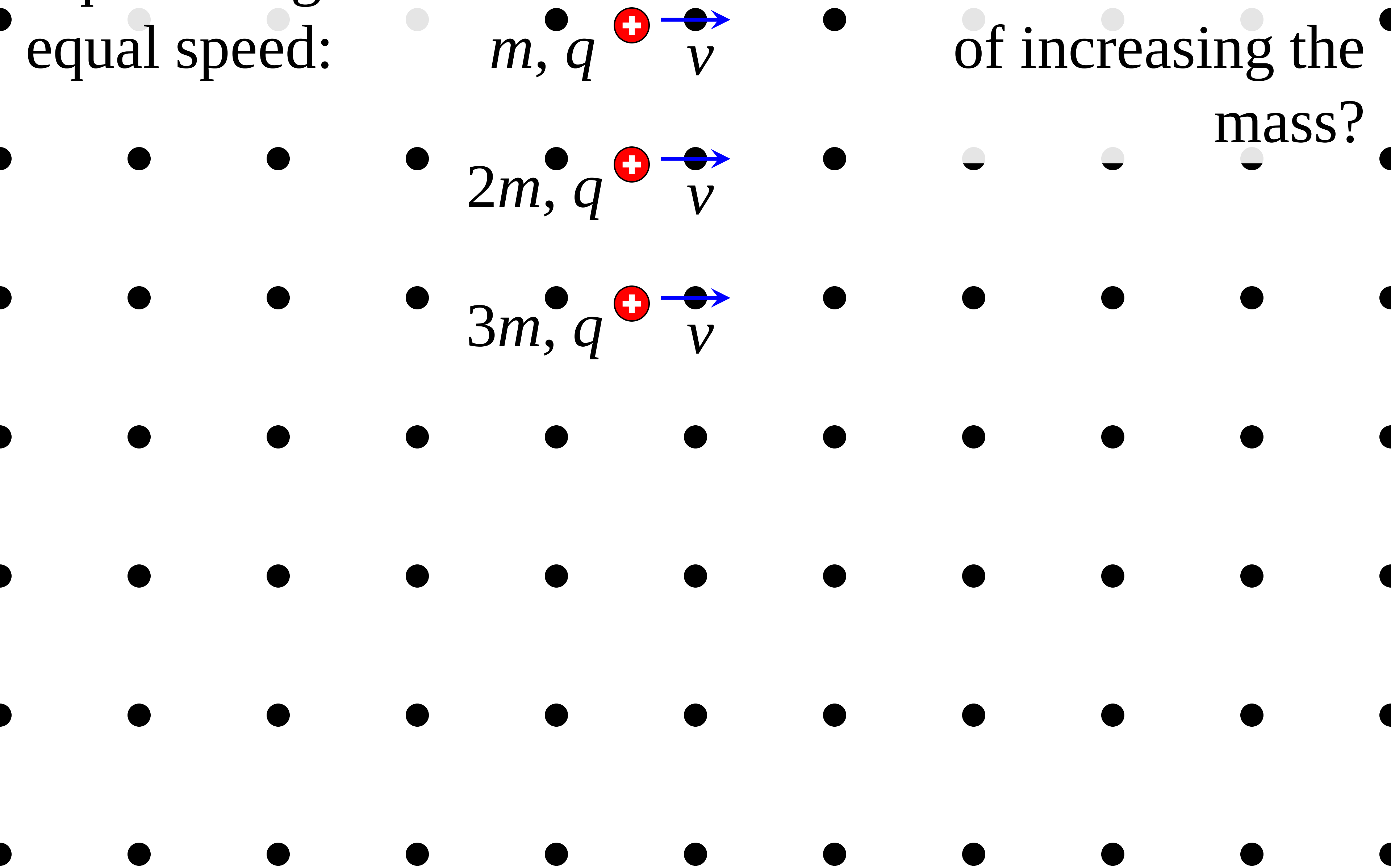
Equal charge and equal mass:

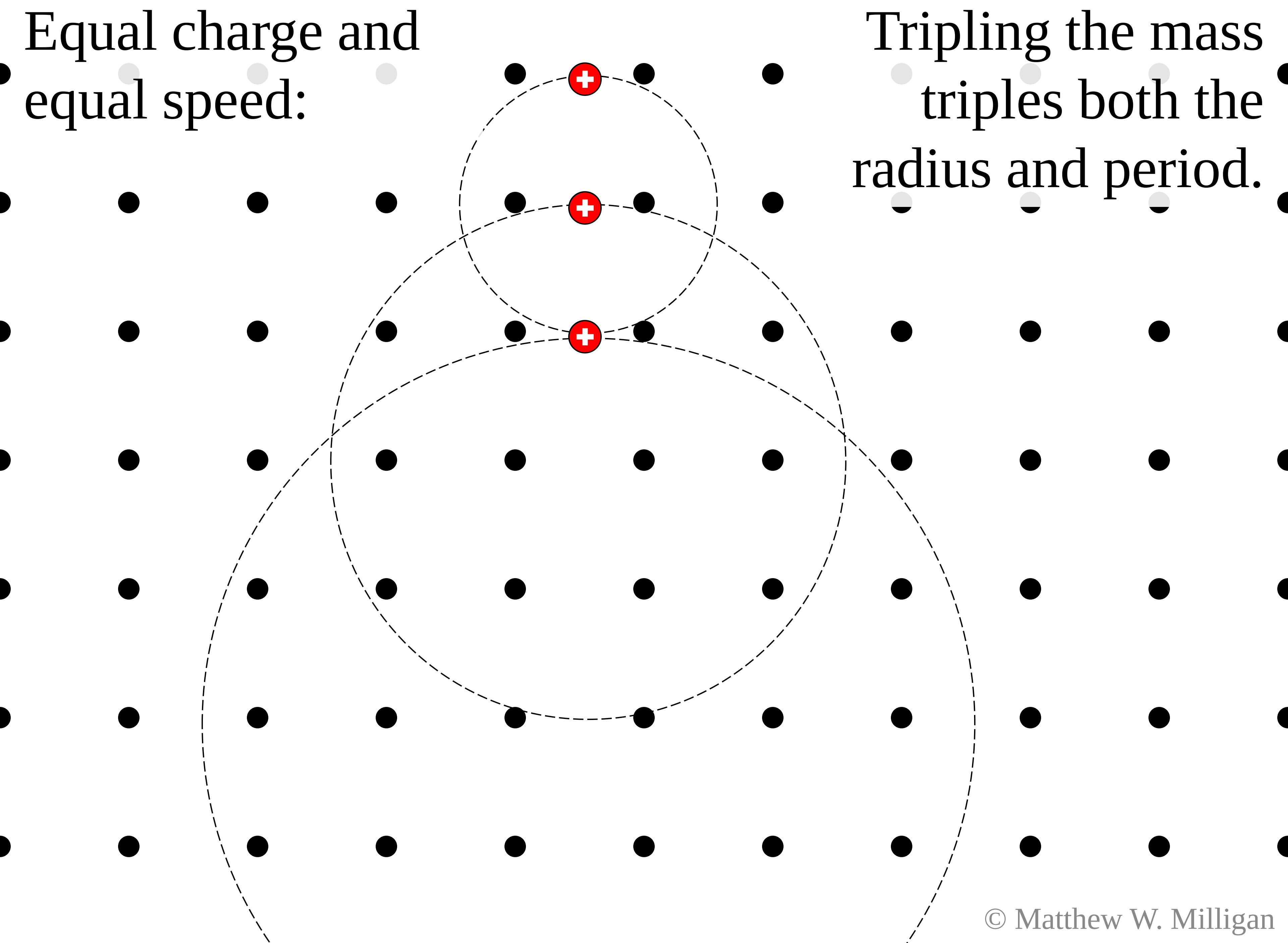
Tripling the speed triples the radius, but has no effect on period.



Equal charge and equal speed:

What is the effect of increasing the mass?




Equal charge and equal speed:
Tripling the mass triples both the radius and period.
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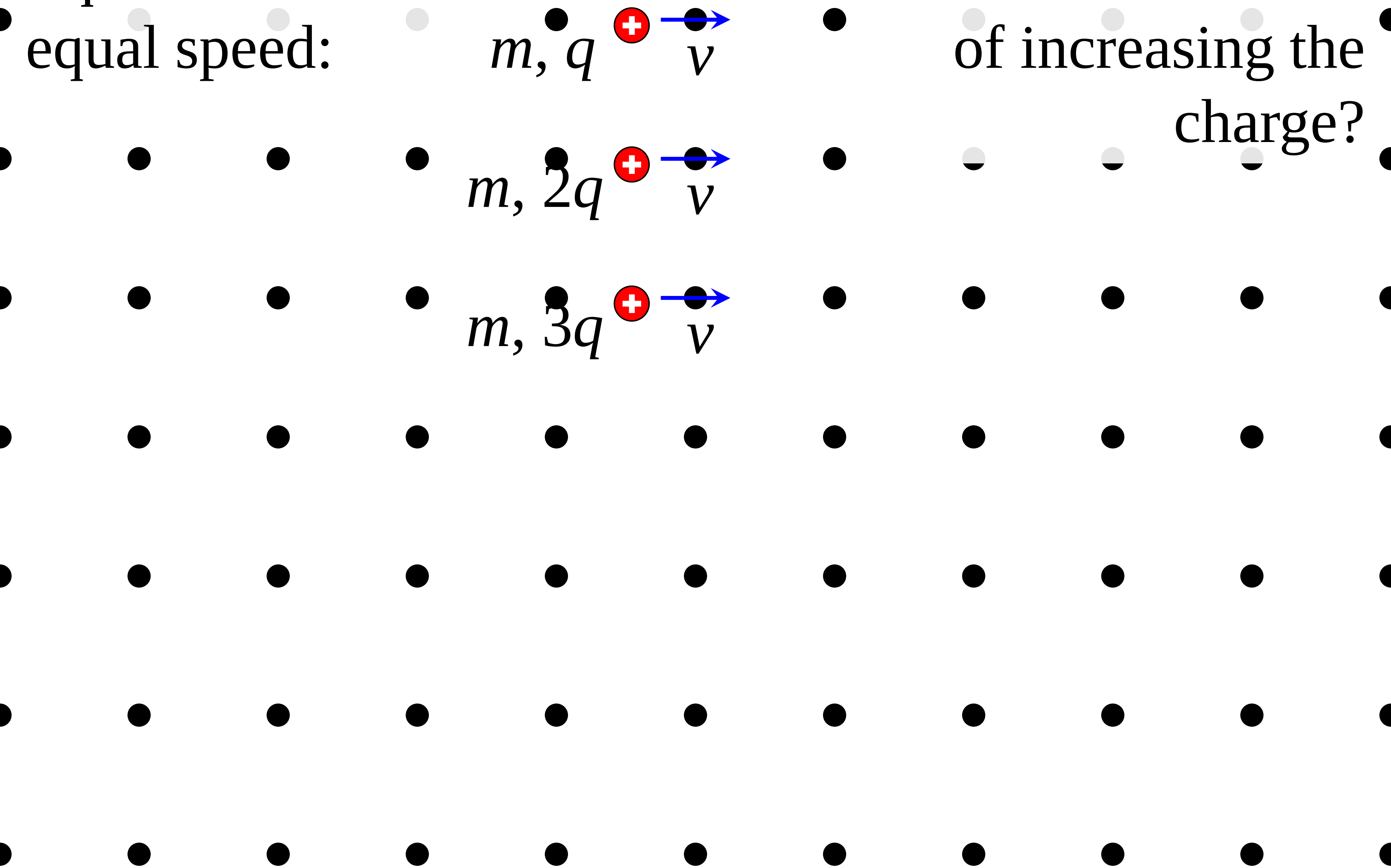
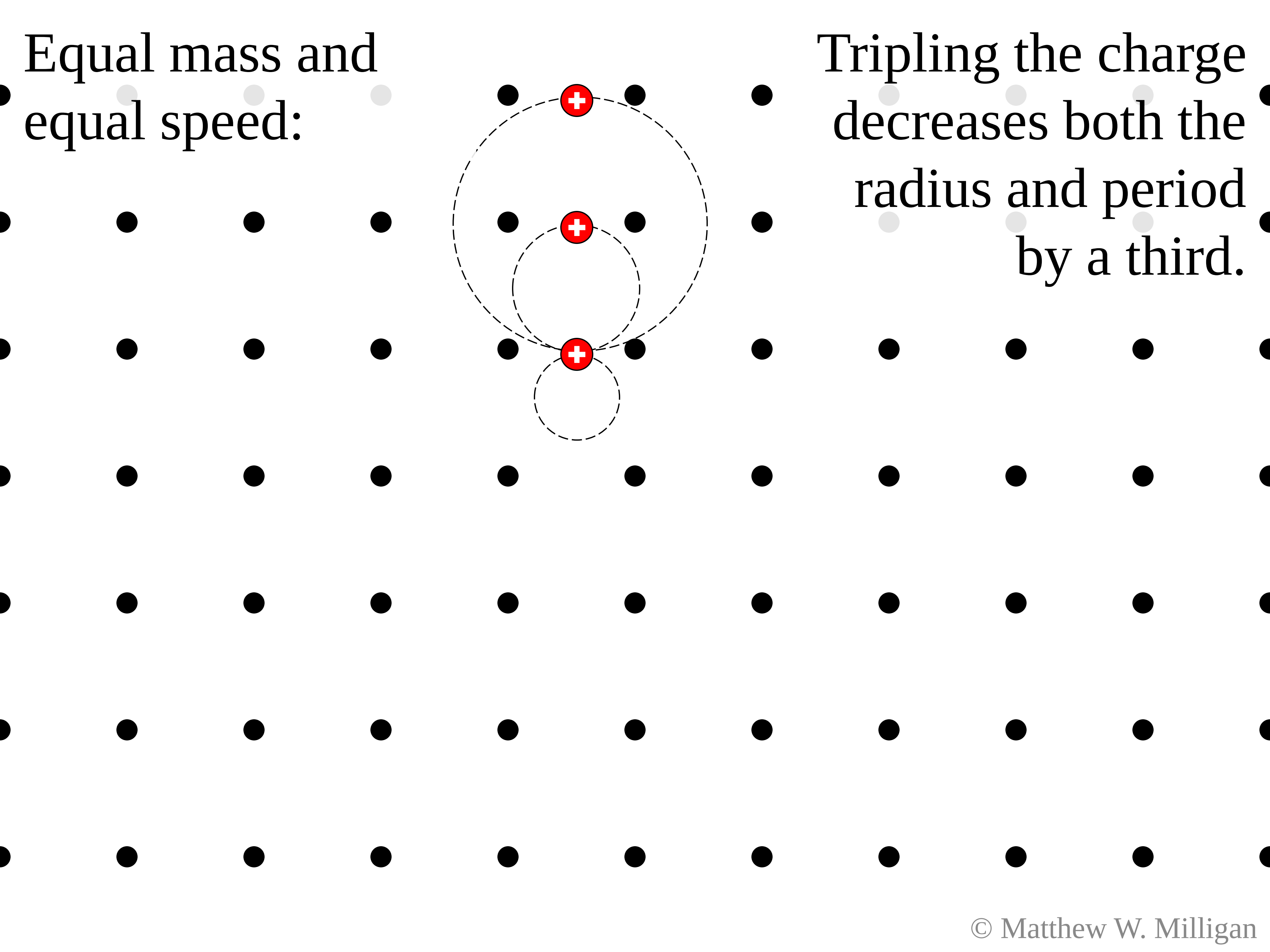
Equal mass and equal speed:

What is the effect of increasing the charge?




Equal mass and
equal speed:
Tripling the charge
decreases both the
radius and period
by a third.
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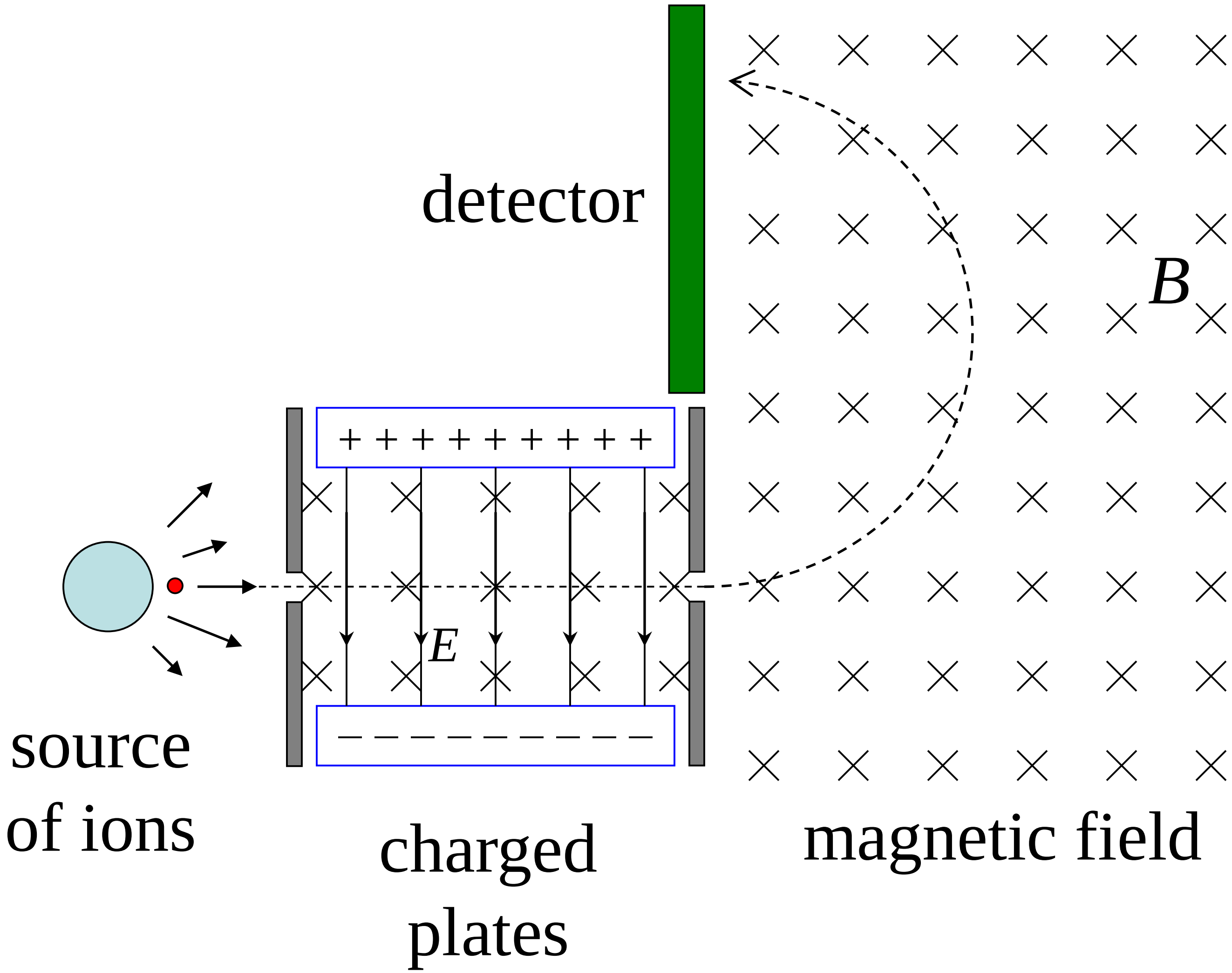
Mass Spectrometer

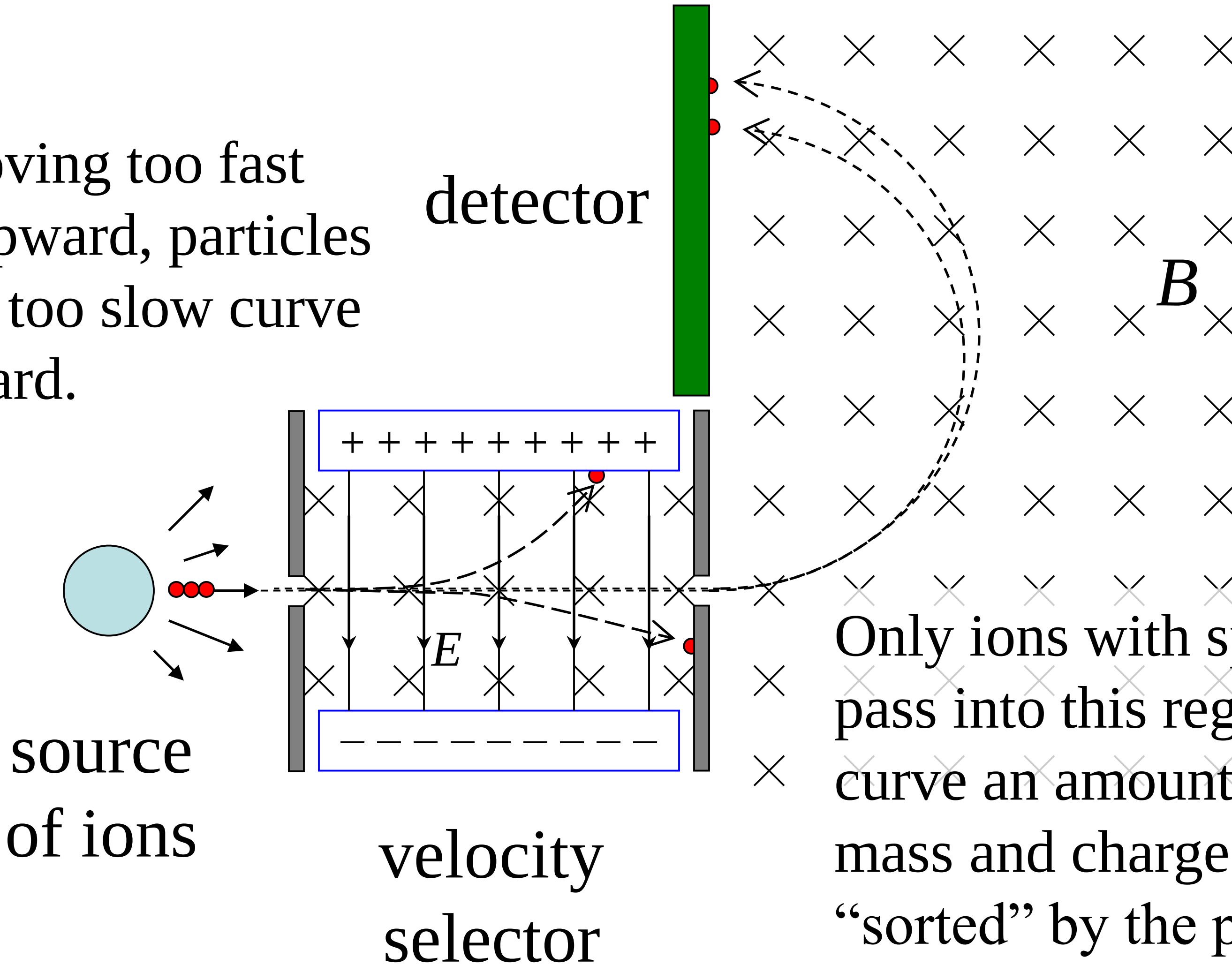
- The behavior of a charged particle moving within a magnetic field depends on its mass.
- This characteristic behavior is exploited by a mass spectrometer – a device that is used to determine the mass of ionized atoms.
- In this device ions from a certain source pass through a velocity selector and enter a region with a uniform magnetic field.
- The radius of the path within the field depends on the charge and mass of the particle.

Mass Spectrometer



Mass Spectrometer

Ions moving too fast curve upward, particles moving too slow curve downward.



Only ions with speed $v = E/B$ pass into this region and curve an amount related to mass and charge and are "sorted" by the position of impact with detector.