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

Special Case

A ***straight*** current carrying wire affected by a ***uniform*** magnetic field results in:

$$\boxed{\vec{F}_m = I\vec{\ell} \times \vec{B}}$$

F = force on the wire
I = current in the wire
B = magnetic field
ℓ = length of wire

Special Case

A ***straight*** current carrying wire affected by a ***uniform*** magnetic field results in:

$$F_M = I\ell B \sin\theta$$

$$F_M = I\ell_{\perp} B = I\ell B_{\perp}$$

F = force on the wire

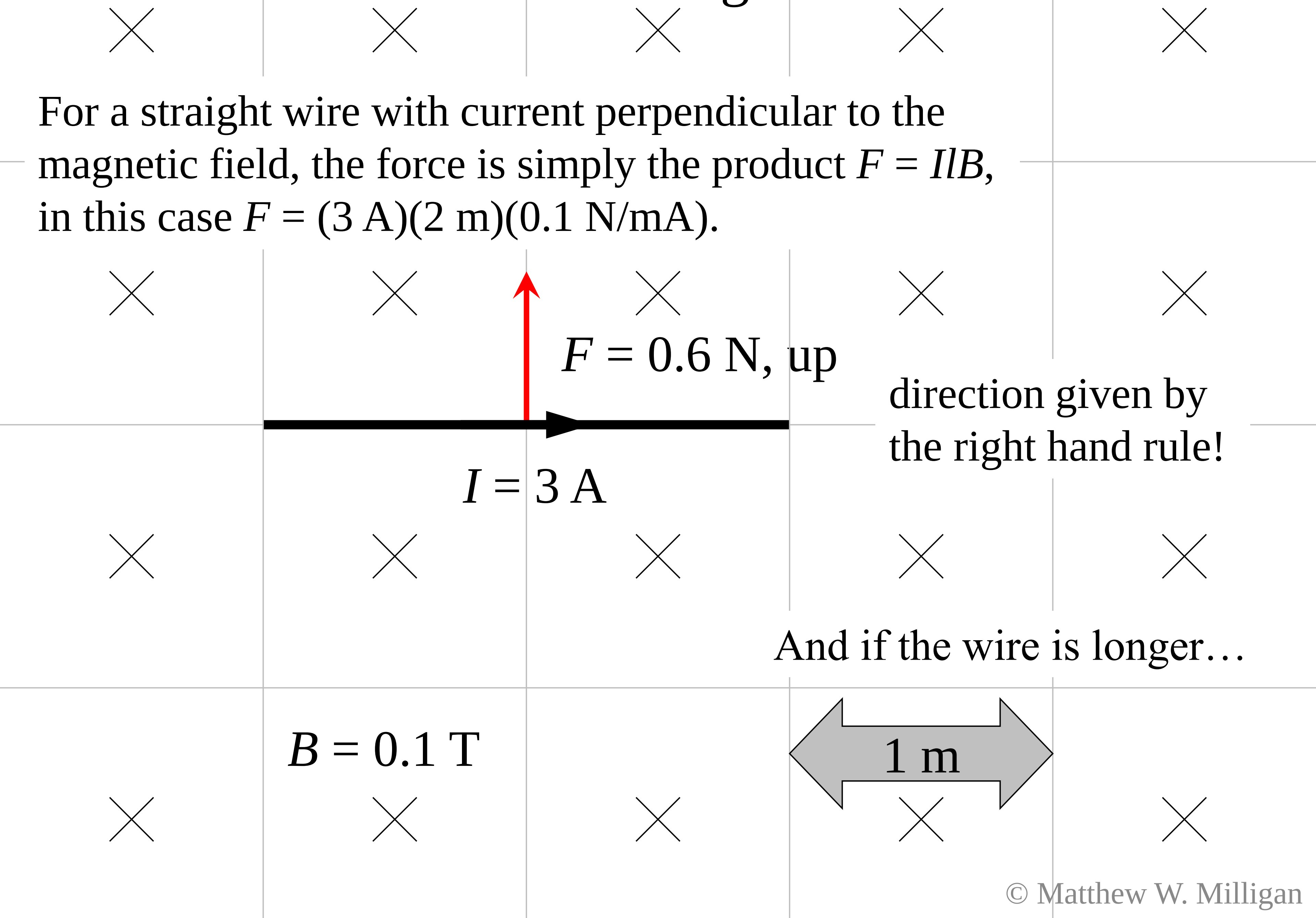
I = current in the wire

B = magnetic field

ℓ = length of wire

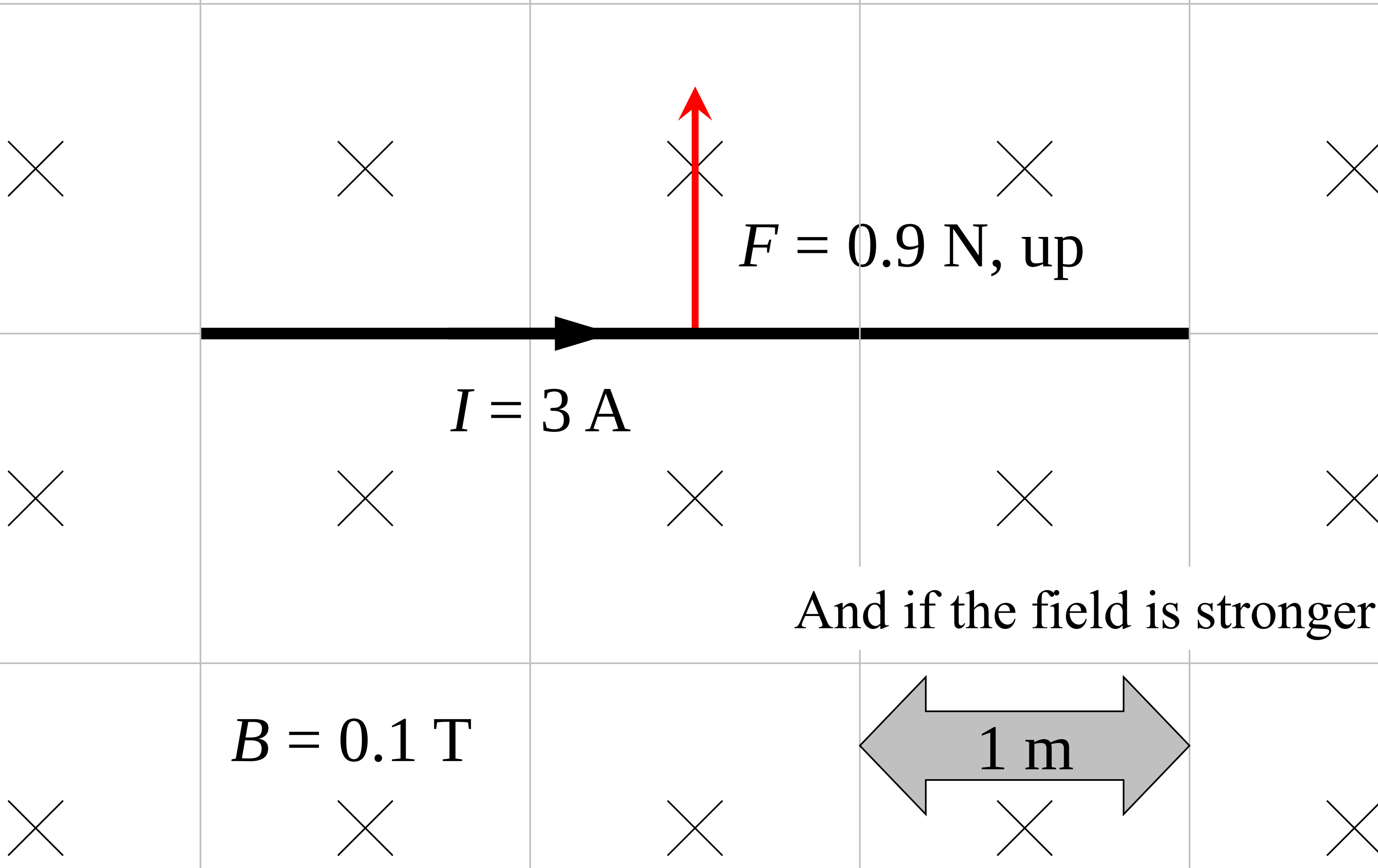
Determine the magnetic force:

For a straight wire with current perpendicular to the magnetic field, the force is simply the product $F = IlB$, in this case F = (3 A)(2 m)(0.1 N/mA).



Determine the magnetic force:

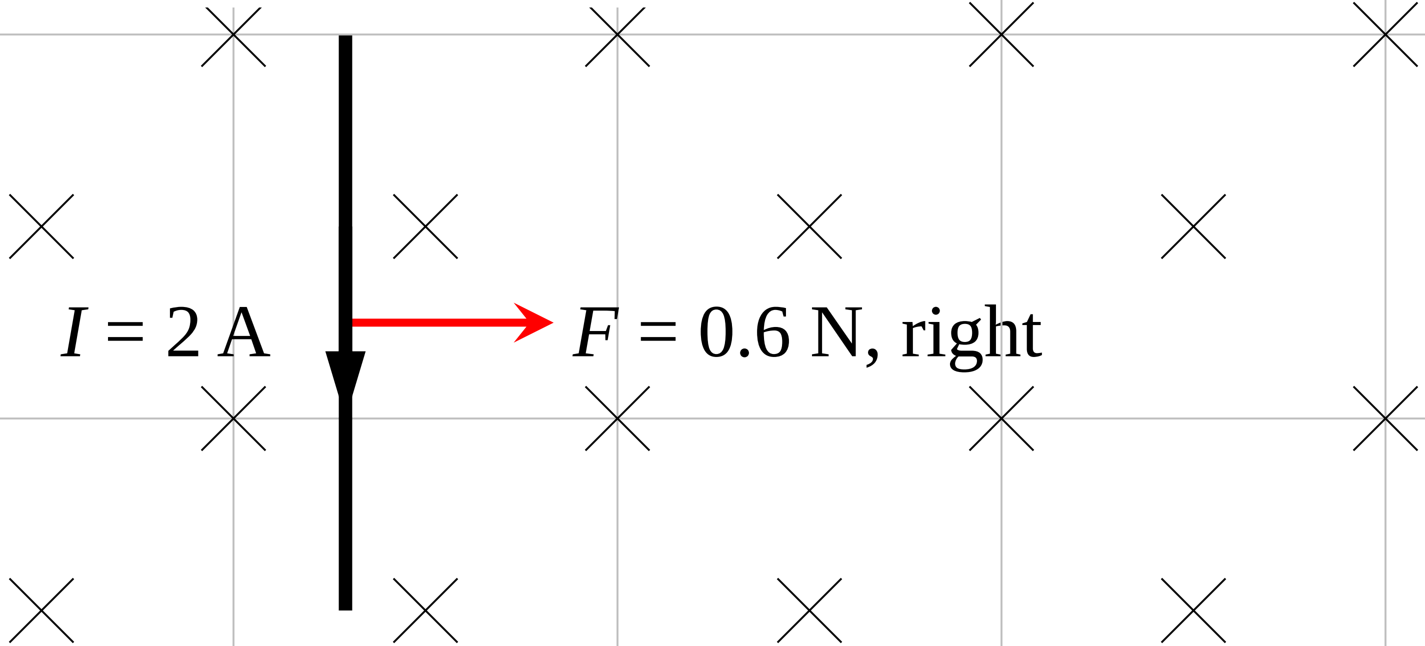
…the force is proportionally greater.



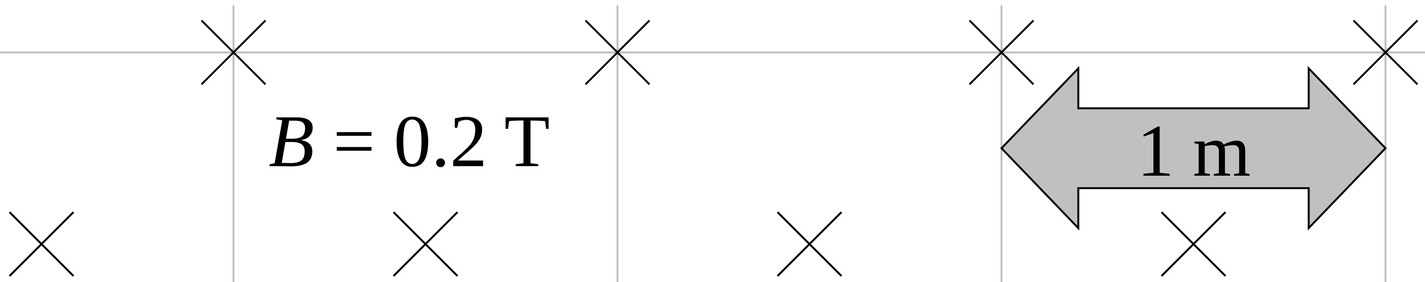
And if the field is stronger…

Determine the magnetic force:

…the force is proportionally greater.

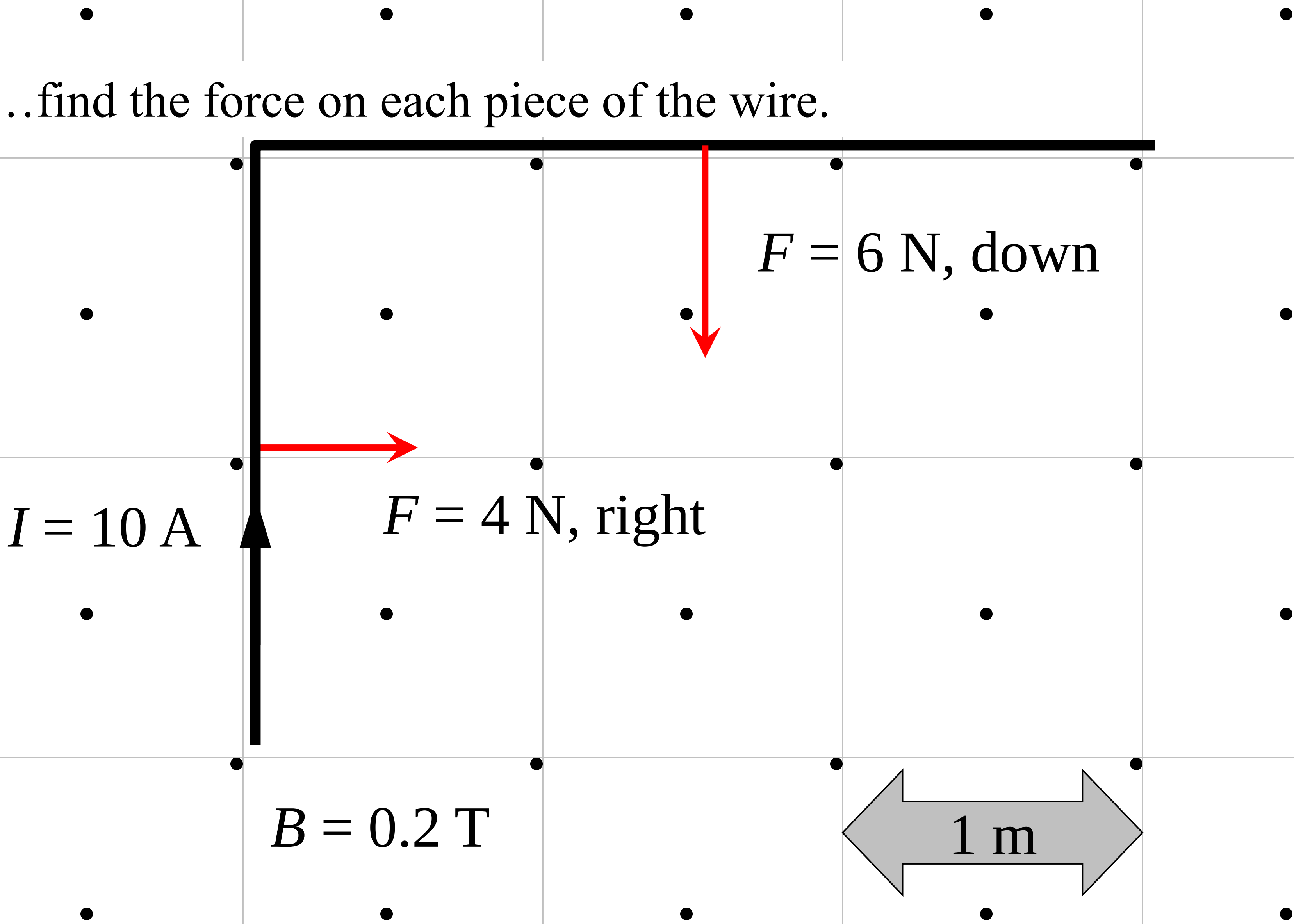


And if field and/or current is reversed and wire is bent…

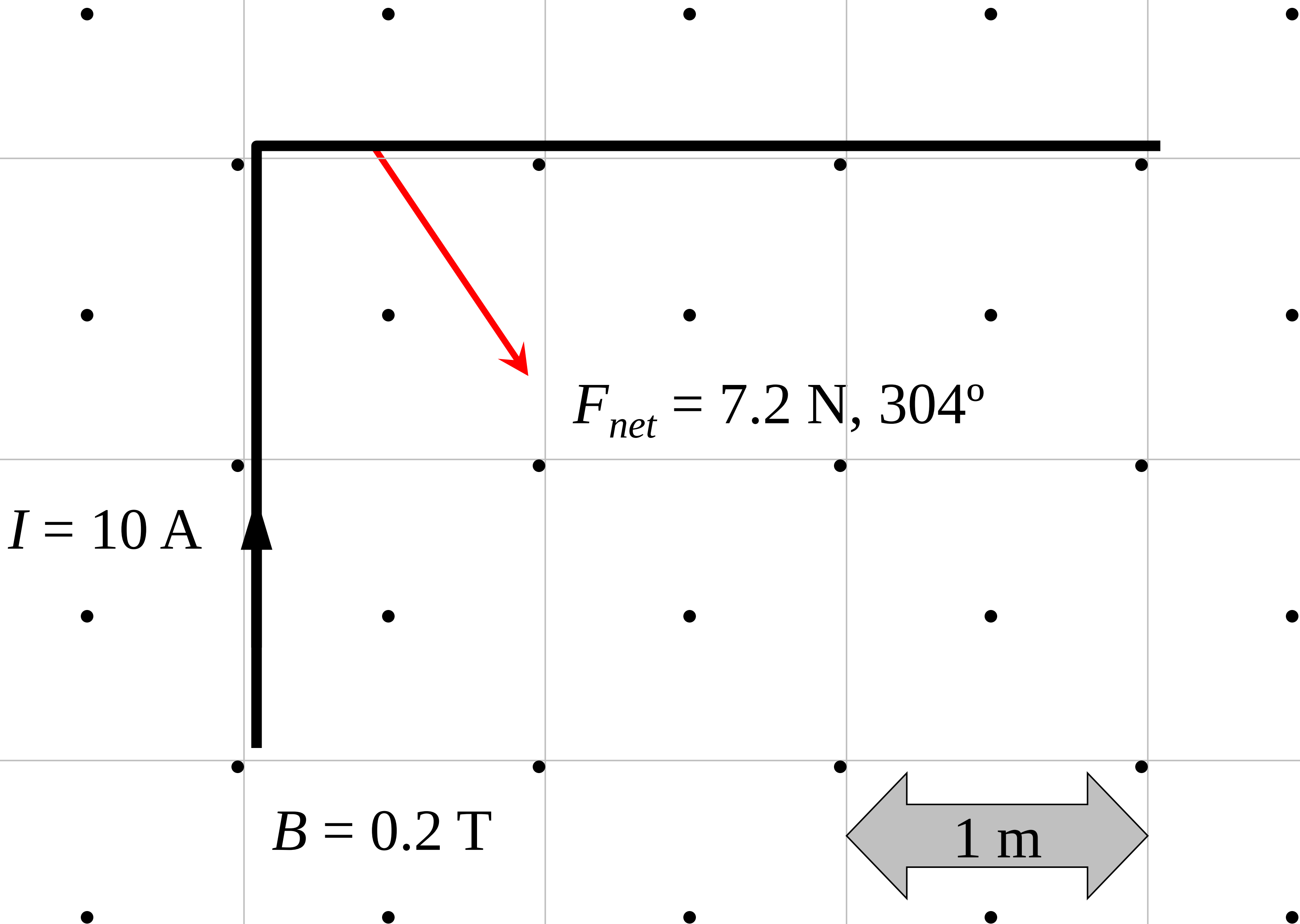


Determine the magnetic force:

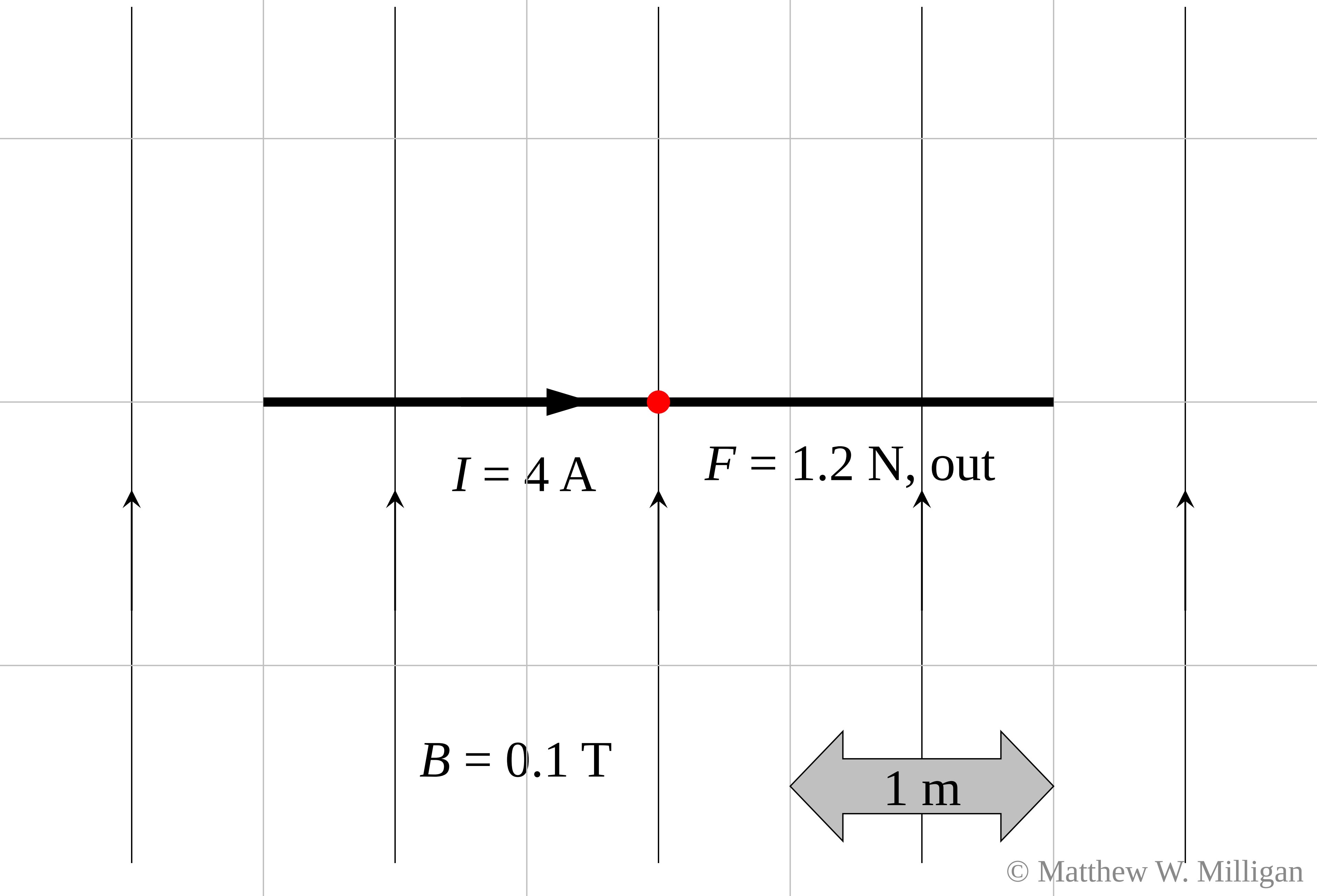
…find the force on each piece of the wire.



Determine the magnetic force:

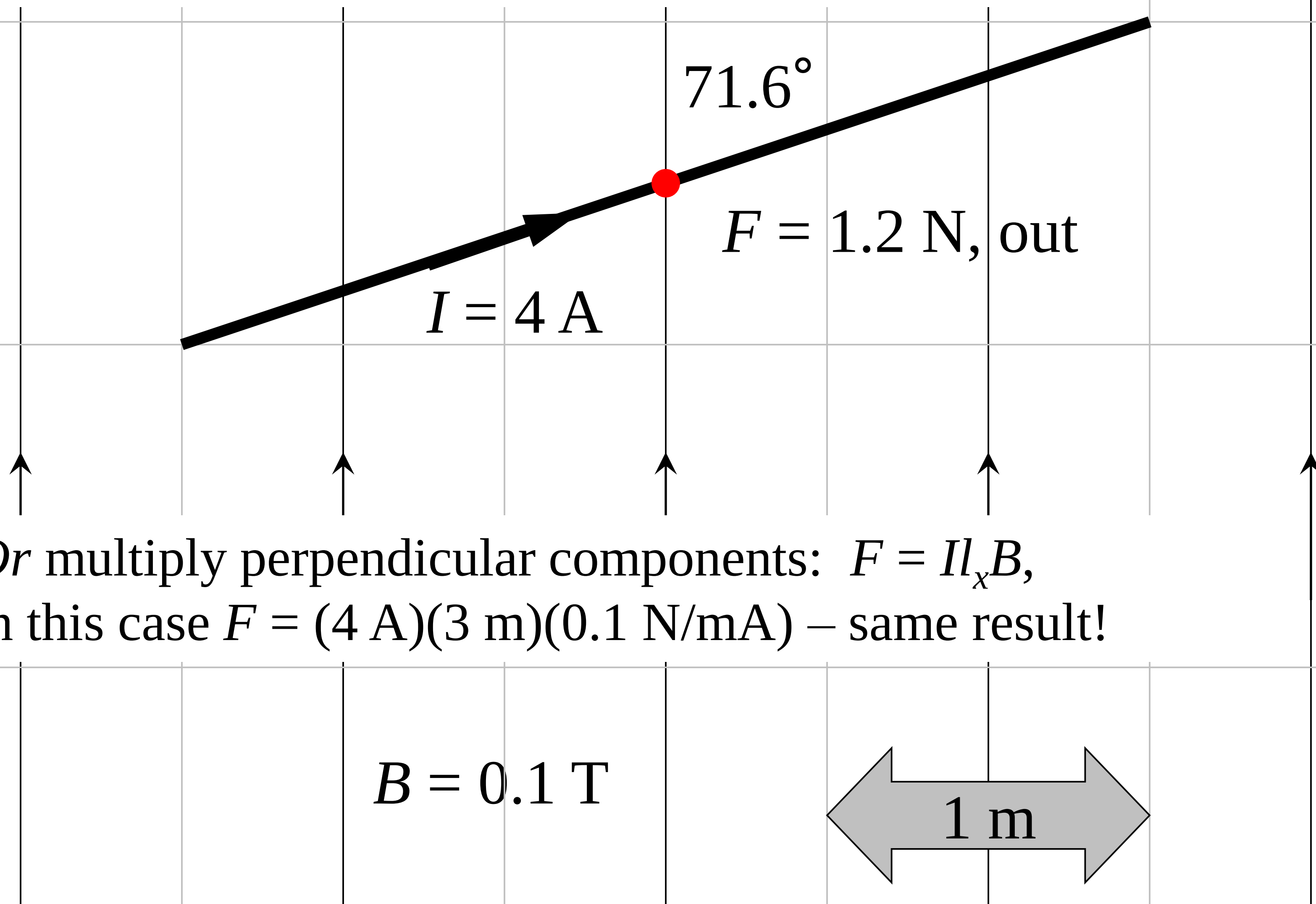


Determine the magnetic force:



Determine the magnetic force:

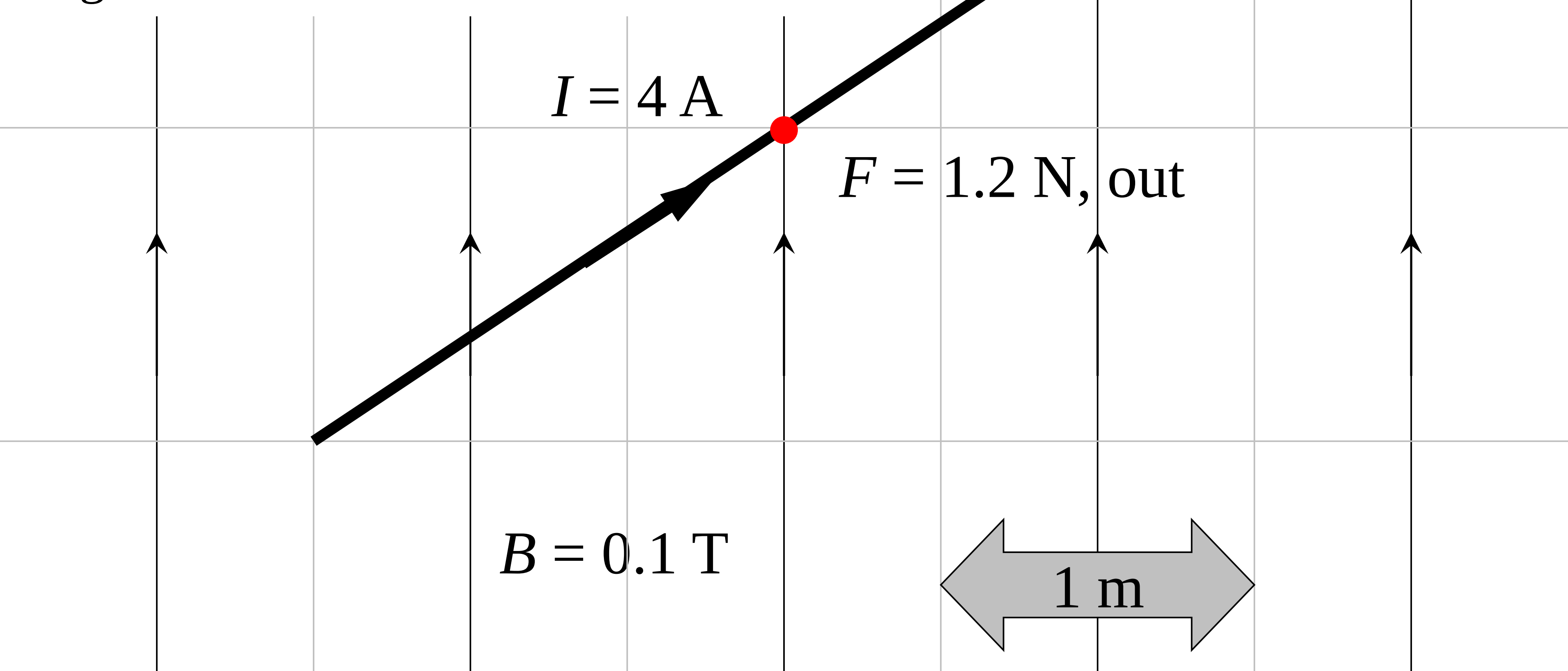
If current is *not* perpendicular use: $F = IlB\sin\theta$,
in this case F = (4 A)(3.16 m)(0.1 N/mA)(sin 71.6º).



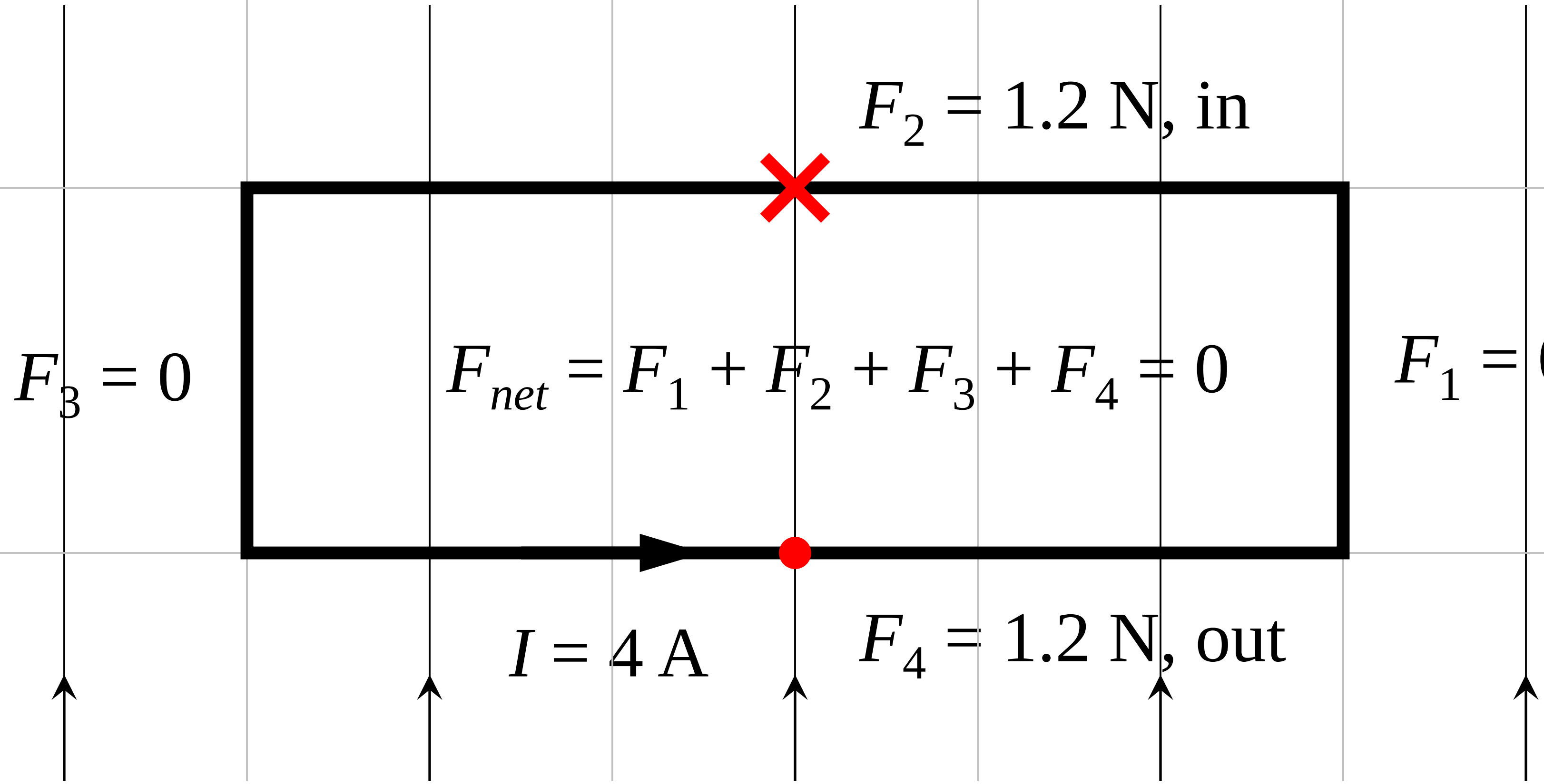
Or multiply perpendicular components: $F = Il_xB$,
in this case F = (4 A)(3 m)(0.1 N/mA) – same result!

Determine the magnetic force:

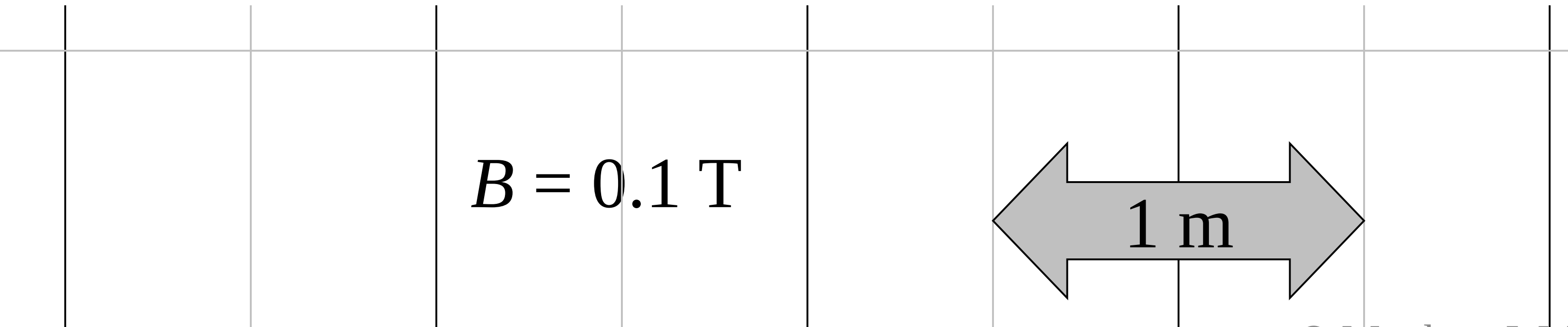
A longer wire than the previous example, *but* the perpendicular *component* of length is the same and therefore the cross product is the same and the result is the same magnetic force.



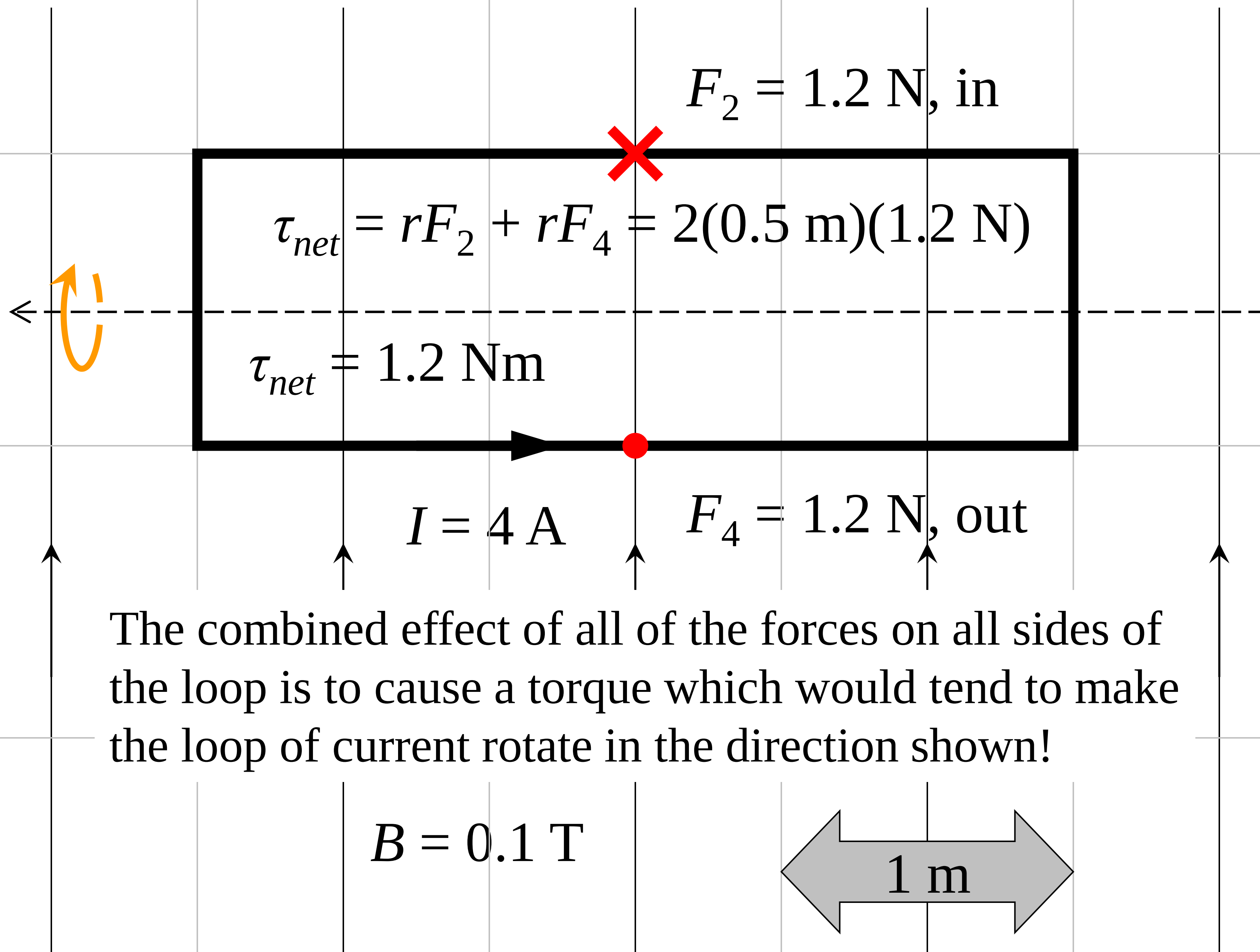
Determine the magnetic force:



Net *force* on the loop of current is *zero*, but what about *torque*?

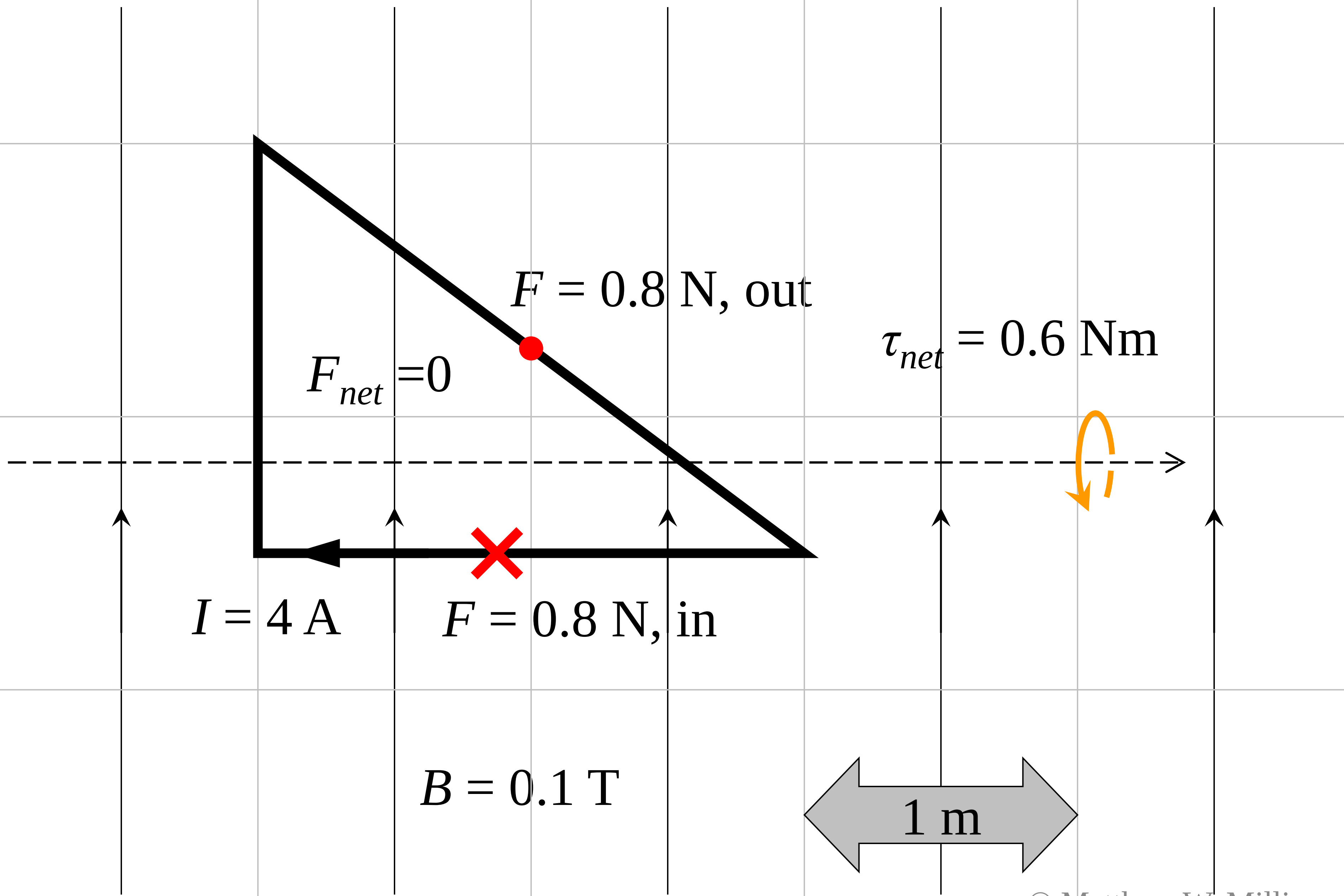


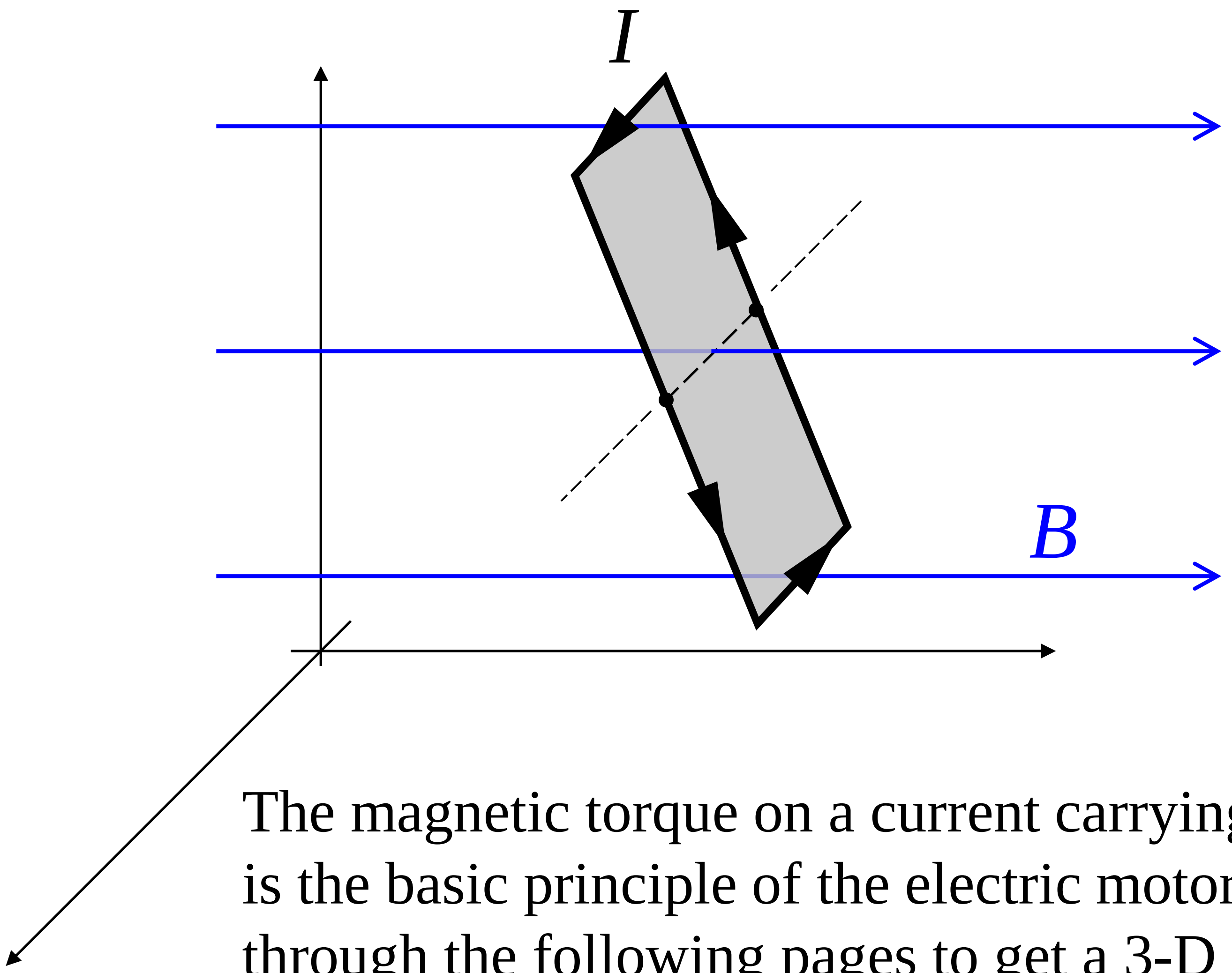
Determine the magnetic <u>torque</u>:



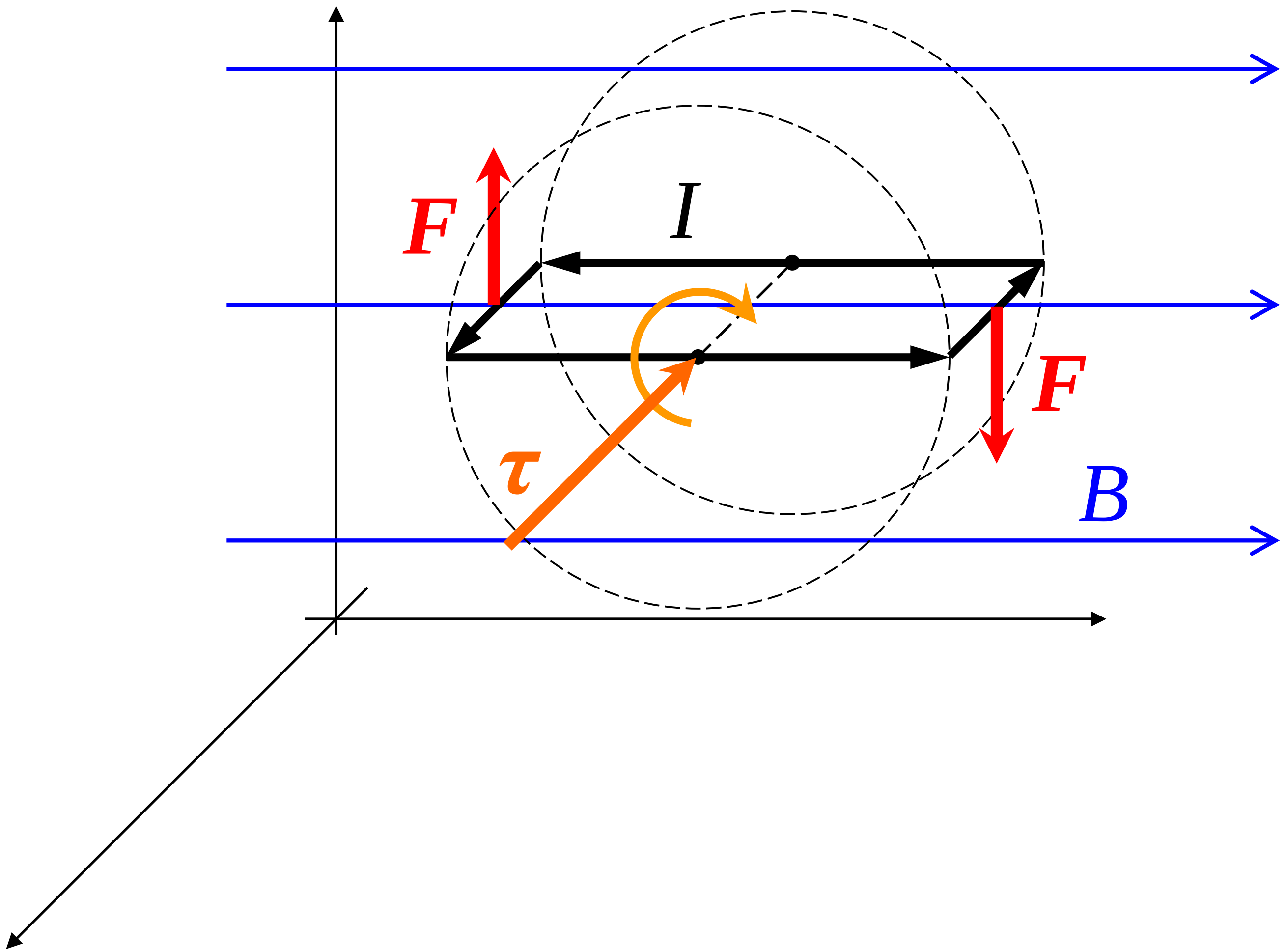
The combined effect of all of the forces on all sides of the loop is to cause a torque which would tend to make the loop of current rotate in the direction shown!

Determine the magnetic force and torque:





The magnetic torque on a current carrying loop of wire is the basic principle of the electric motor. Flip through the following pages to get a 3-D perspective of the changing torque as the loop rotates in a uniform magnetic field…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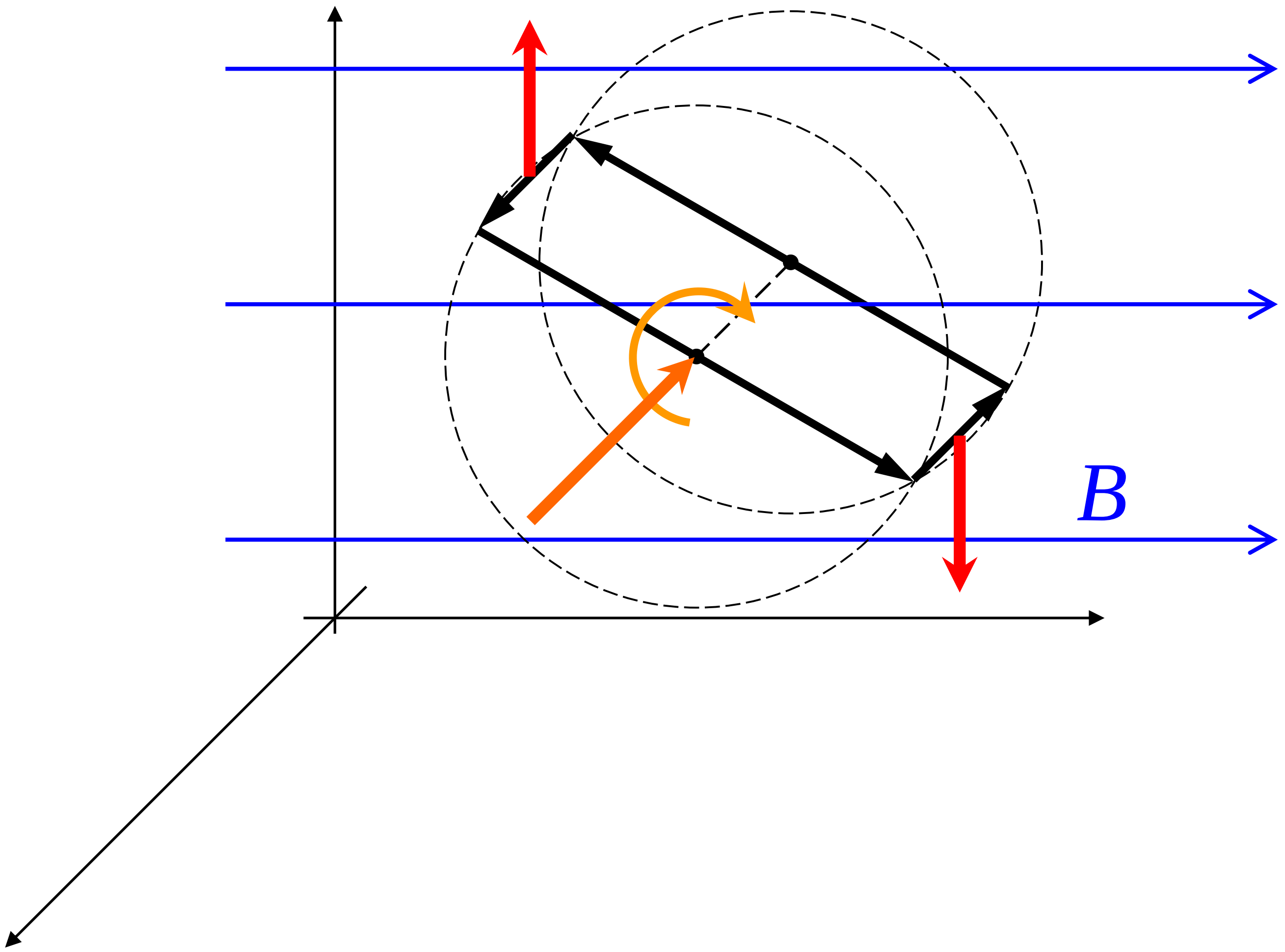
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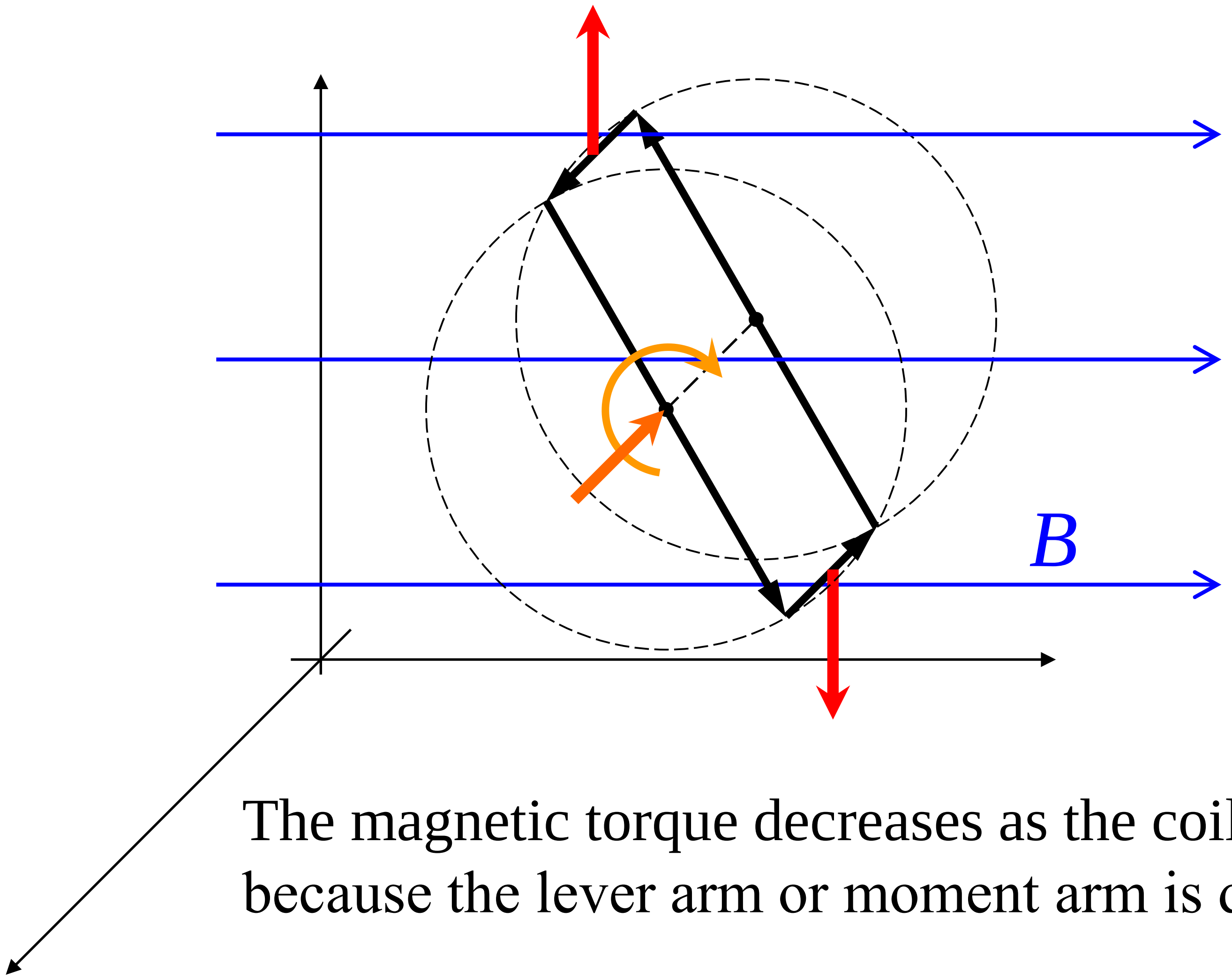
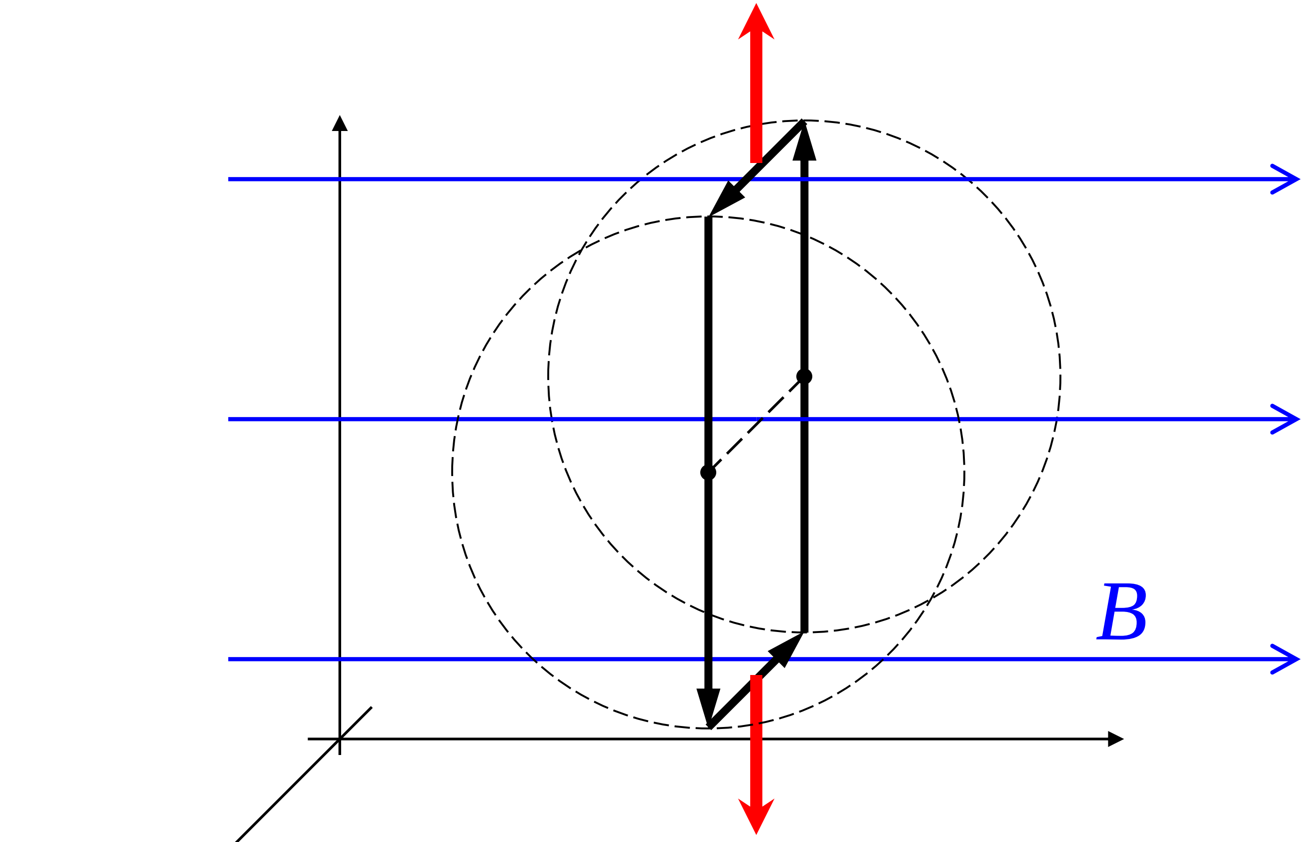
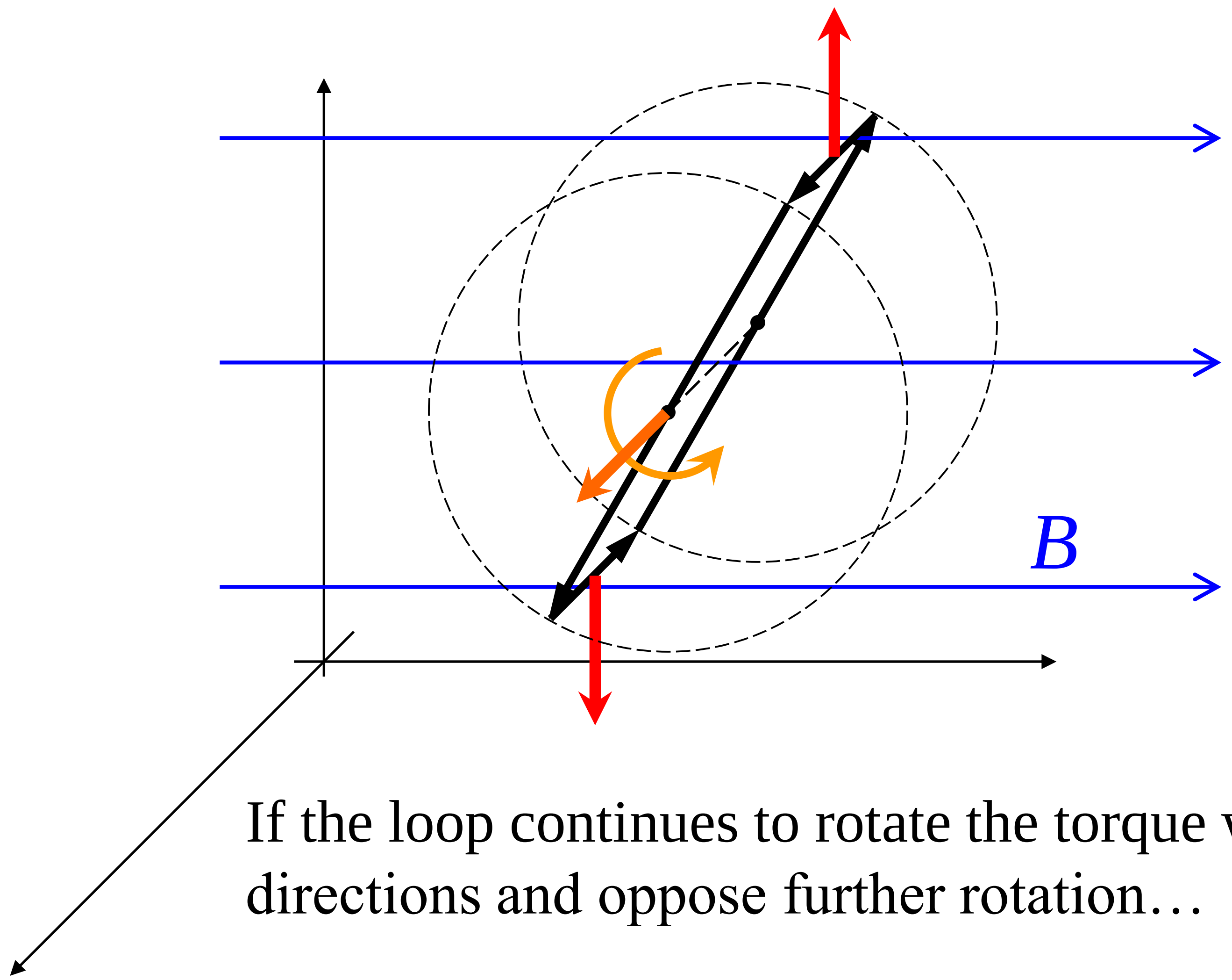


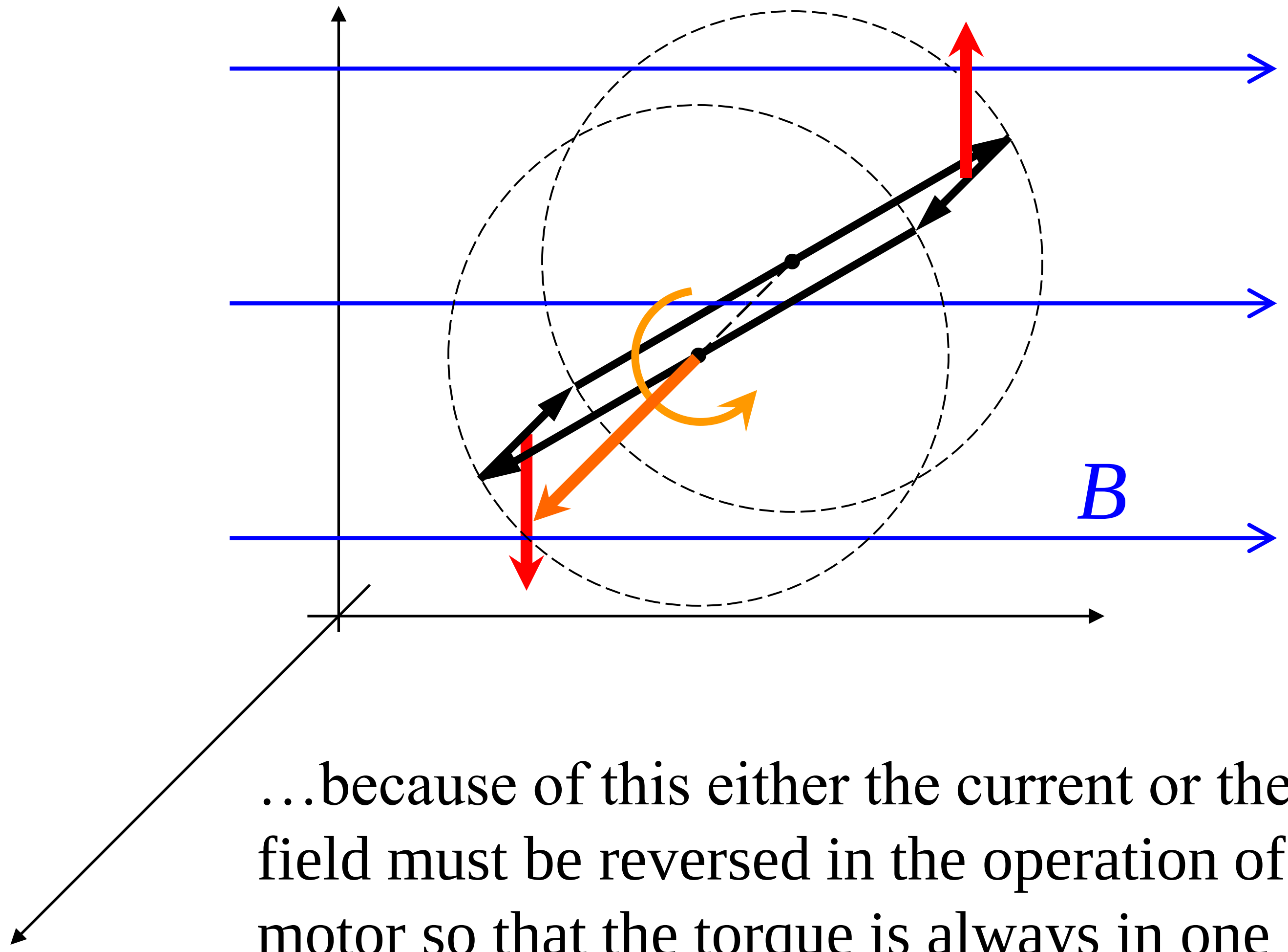
The magnetic torque decreases as the coil rotates because the lever arm or moment arm is decreasing…



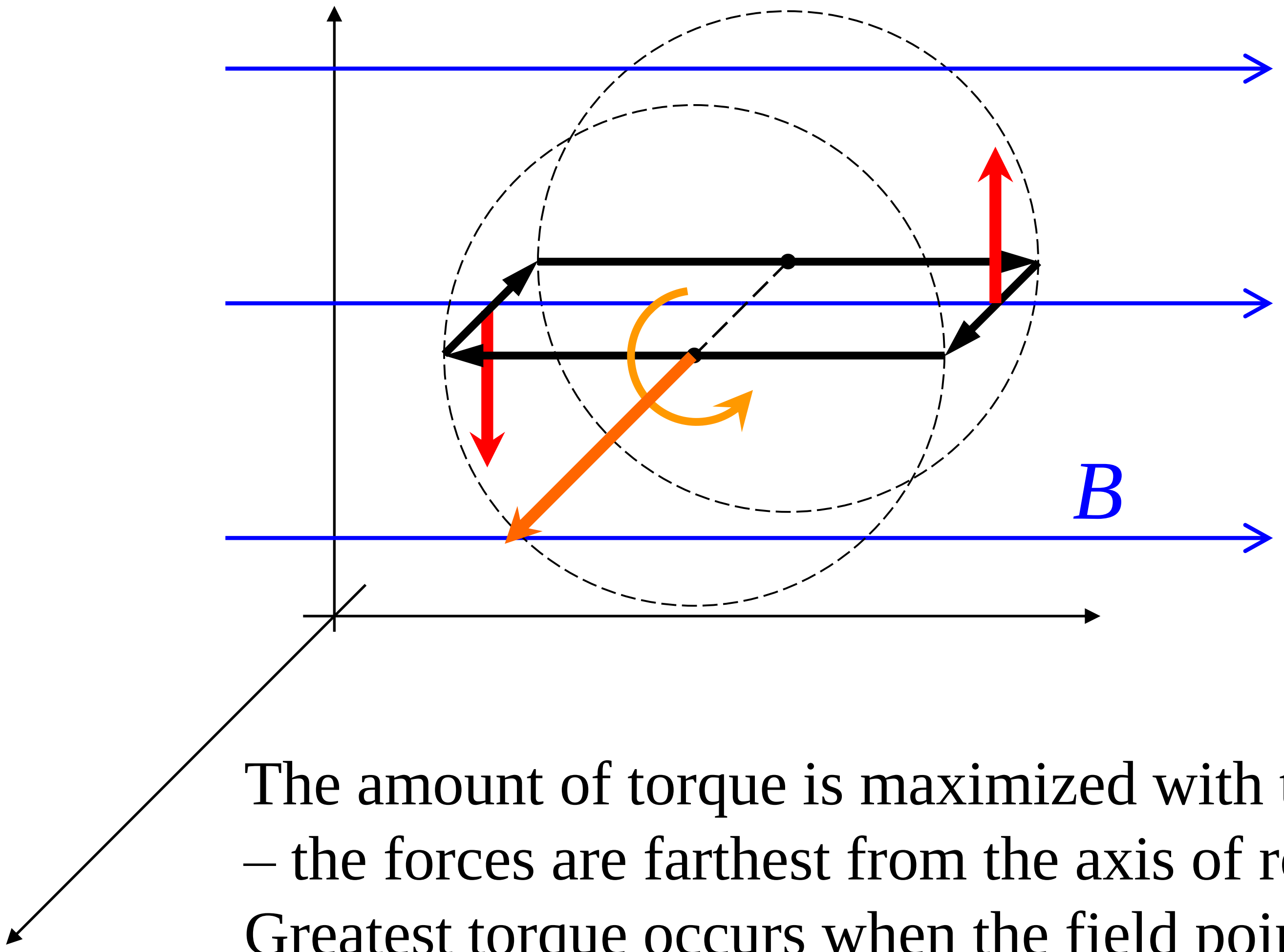
The torque is zero at this point because the forces point directly away from the axis of rotation.



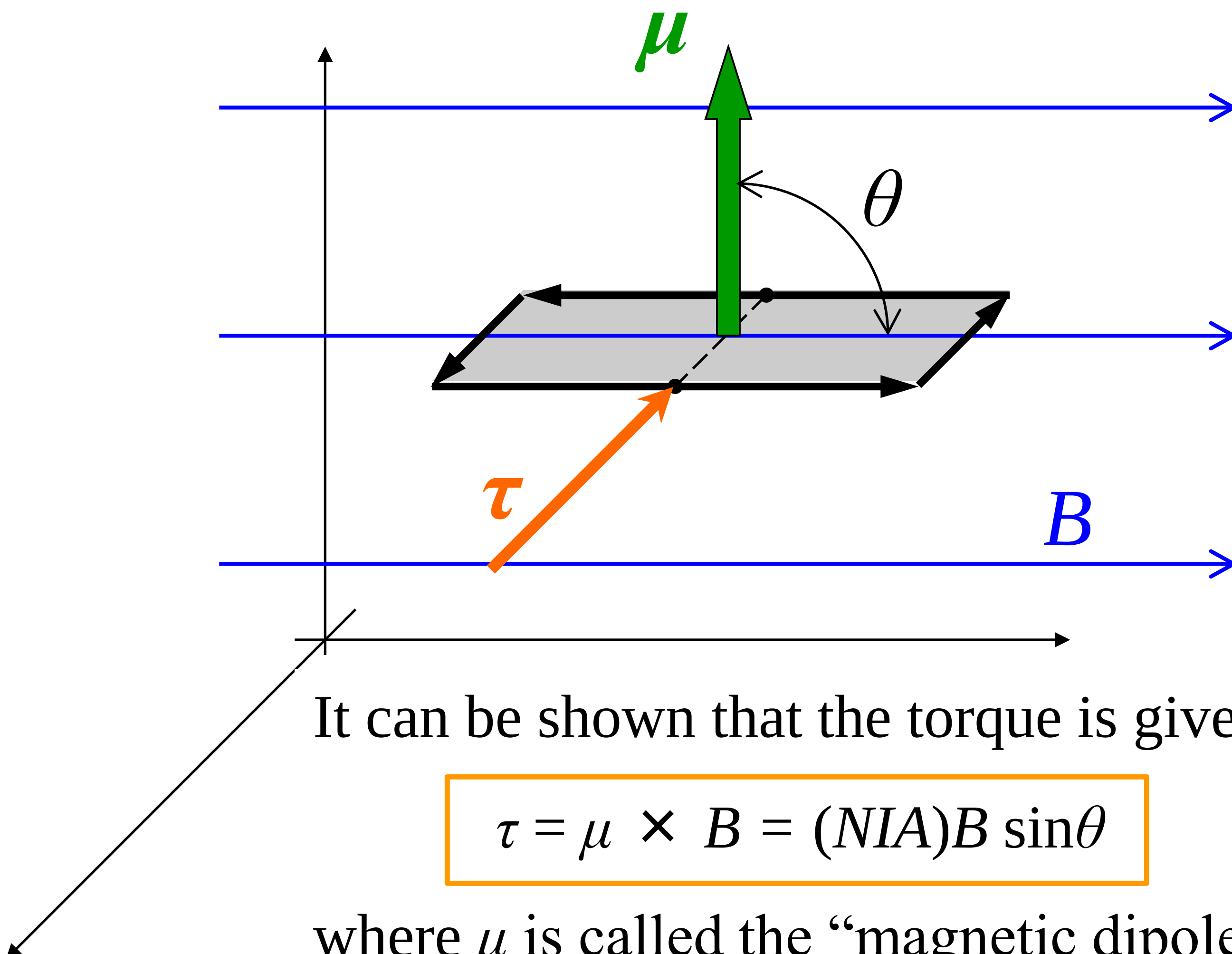
If the loop continues to rotate the torque will reverse directions and oppose further rotation…



…because of this either the current or the magnetic field must be reversed in the operation of an electric motor so that the torque is always in one direction.



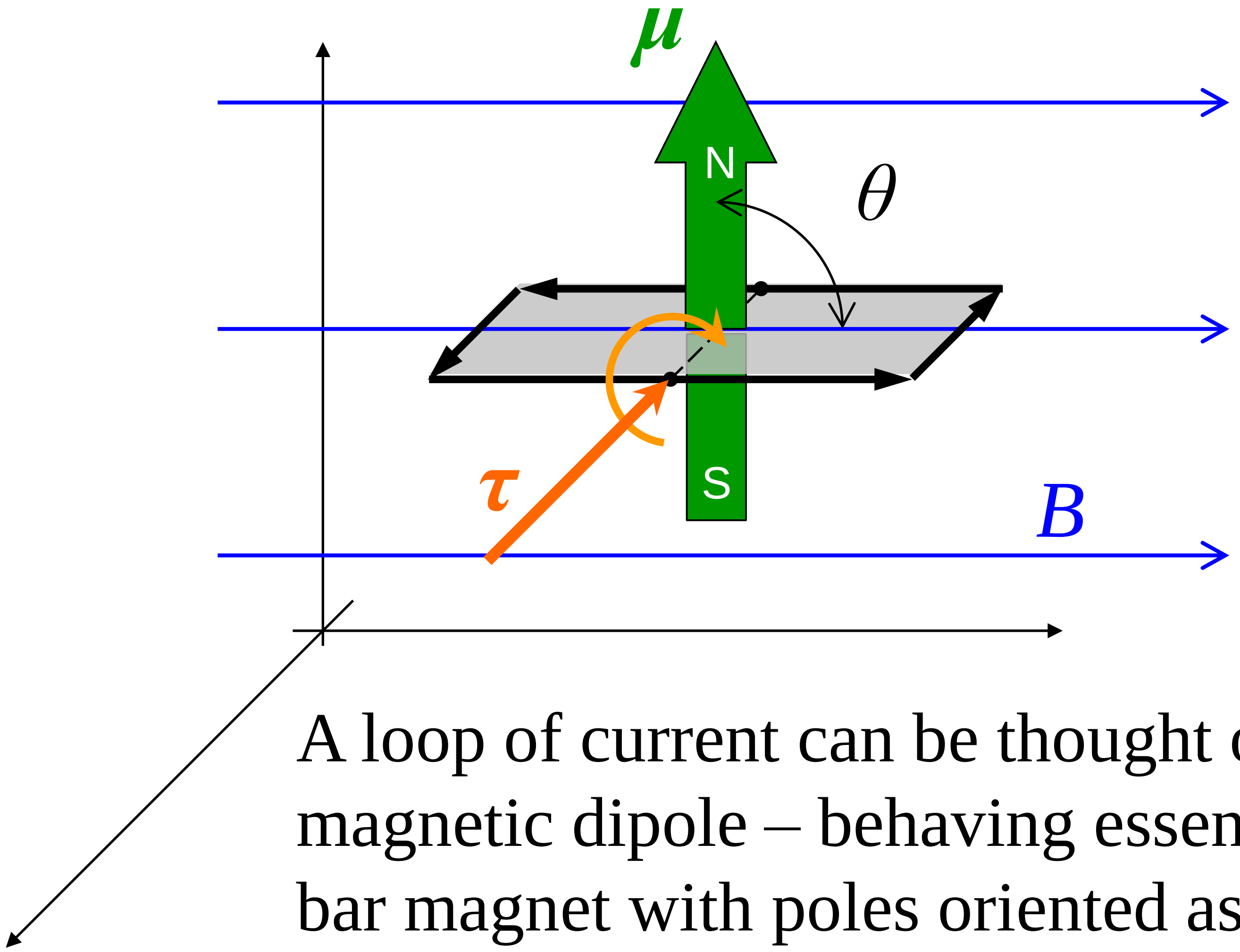
The amount of torque is maximized with this orientation – the forces are farthest from the axis of rotation. Greatest torque occurs when the field points across the area bound by the loop of current carrying wire.



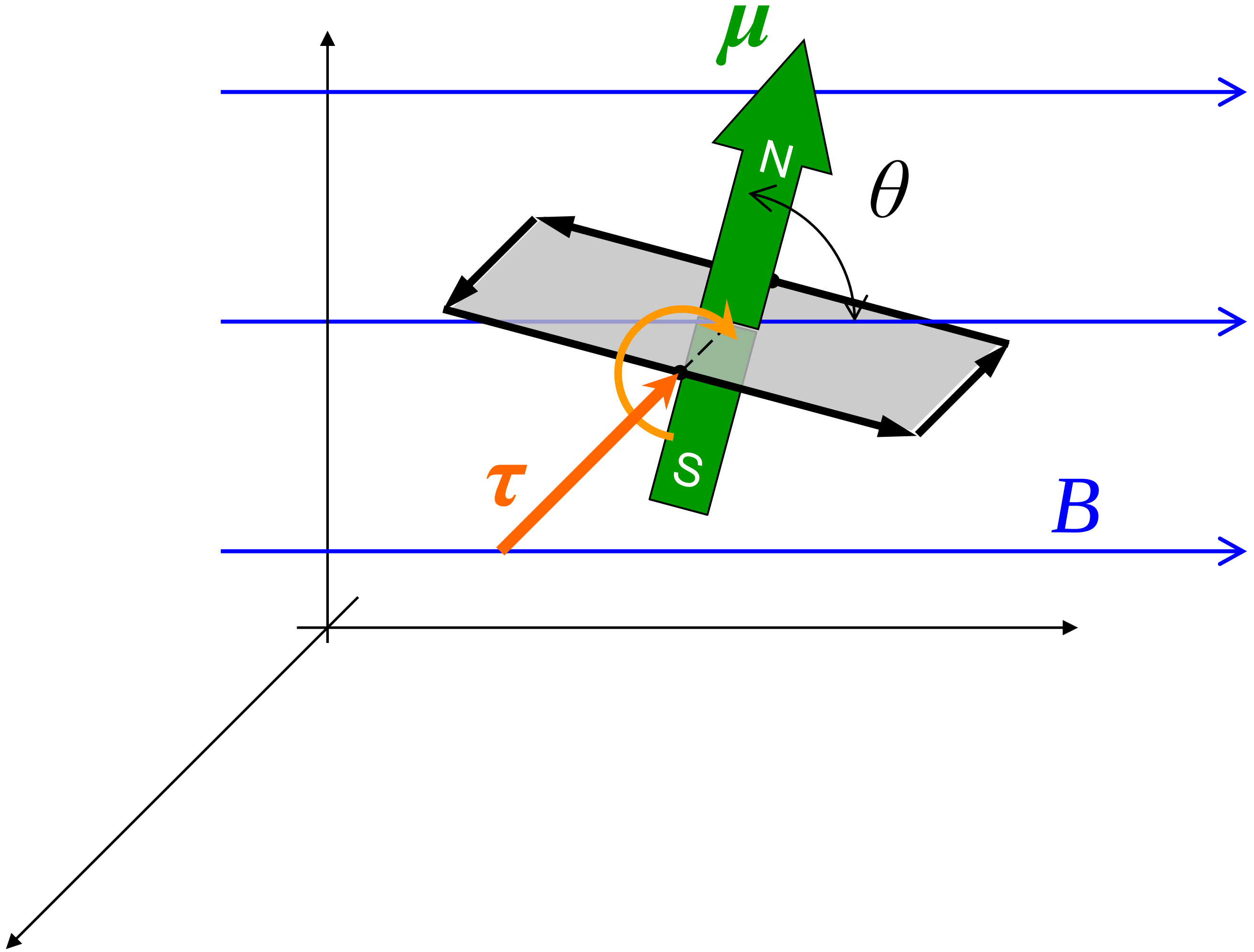
It can be shown that the torque is given by:

$$\boxed{\tau = \mu \times B = (NIA)B\sin\theta}$$

where μ is called the "magnetic dipole moment" and equals the product of number of turns N, current I, and the area A bound by the current.



A loop of current can be thought of as a magnetic dipole – behaving essentially as a bar magnet with poles oriented as shown here.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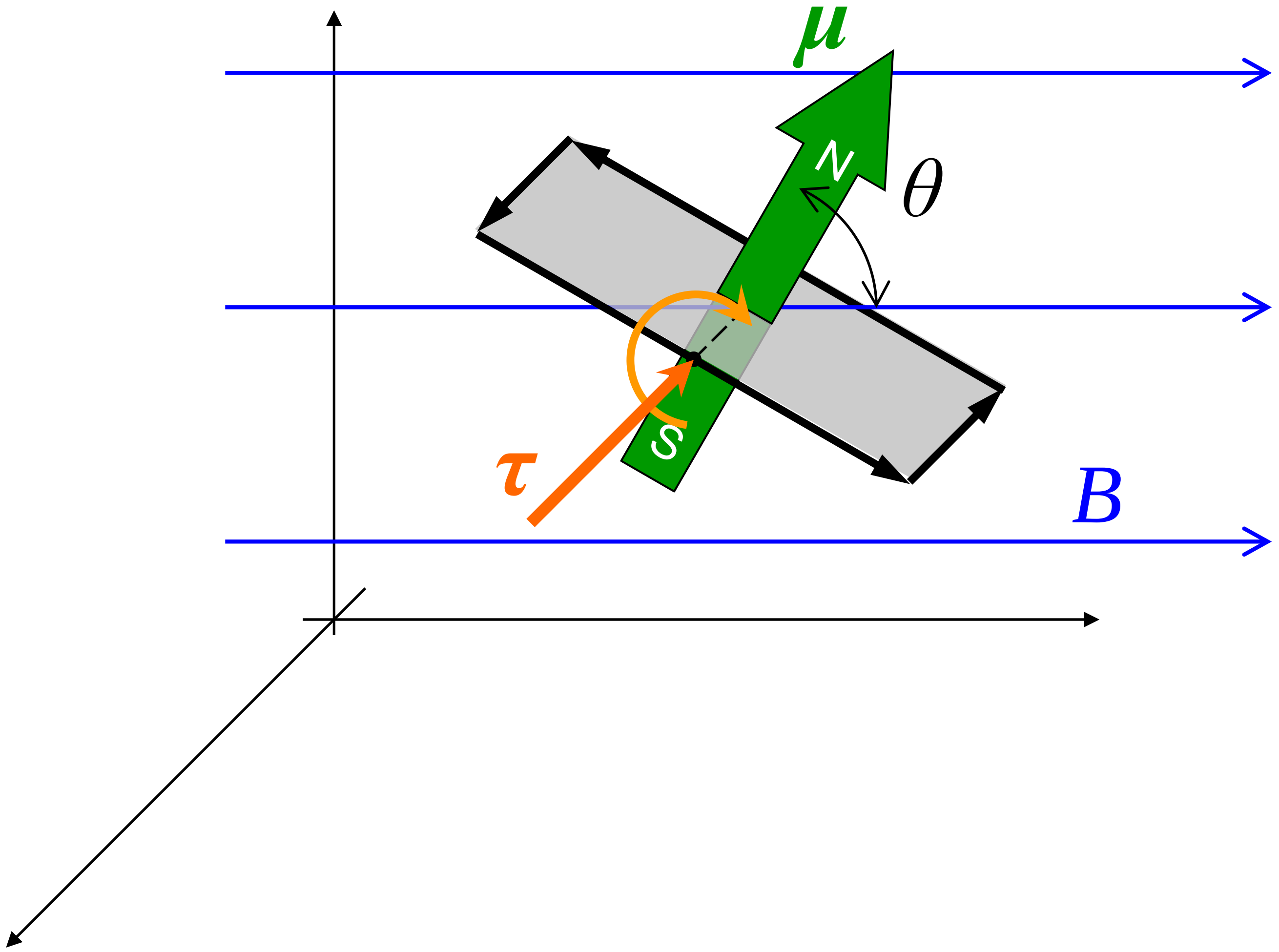

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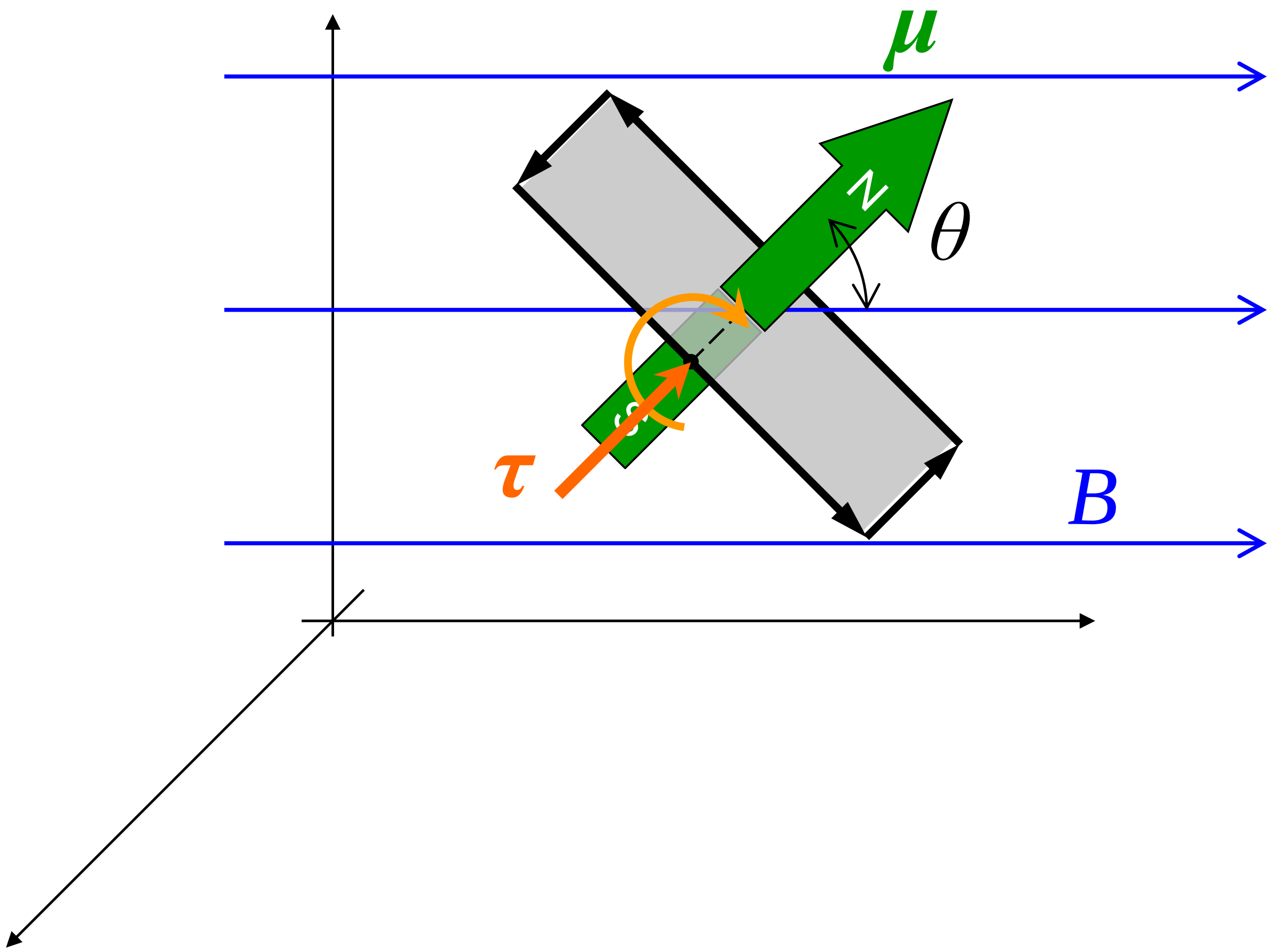
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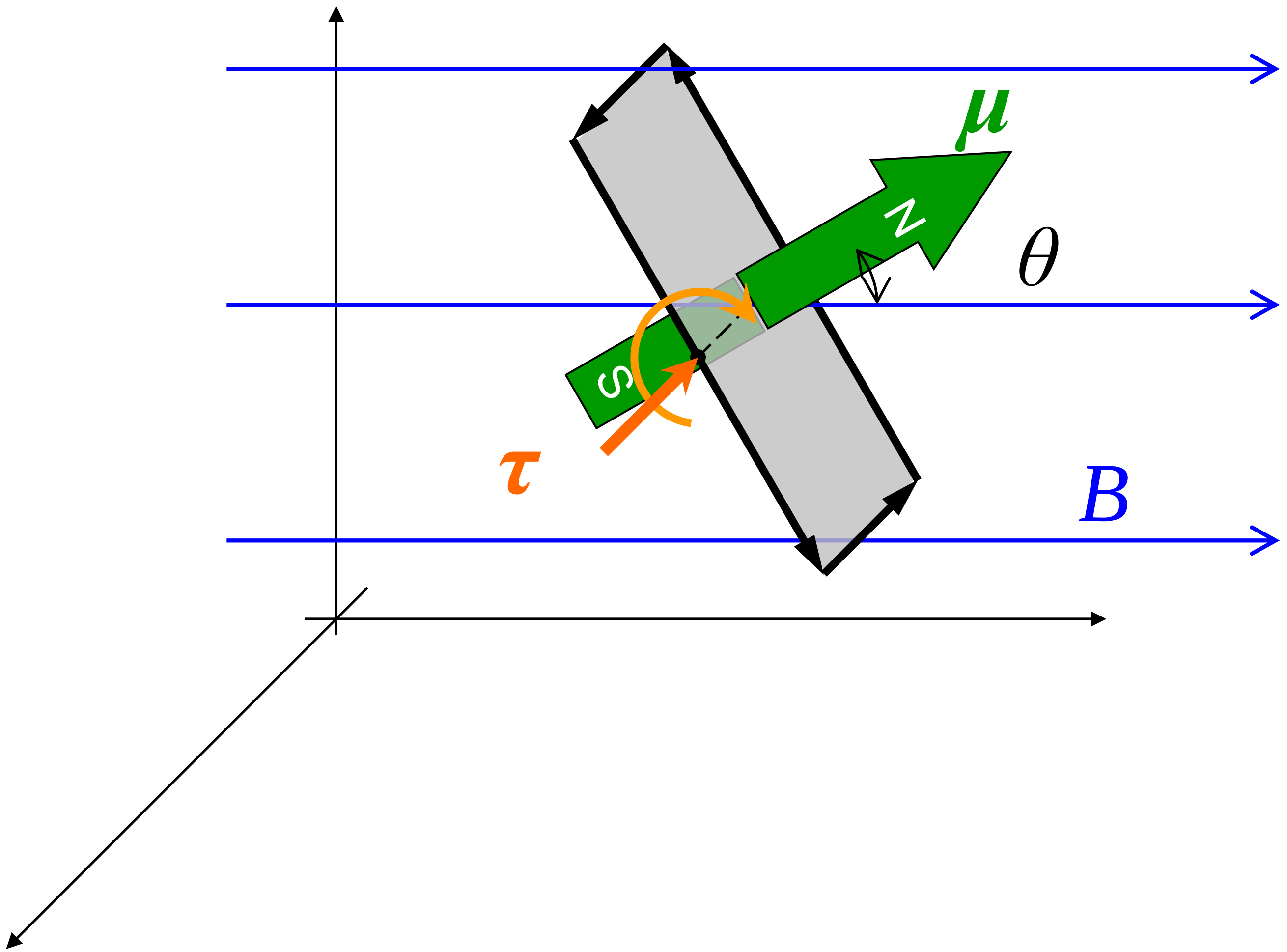

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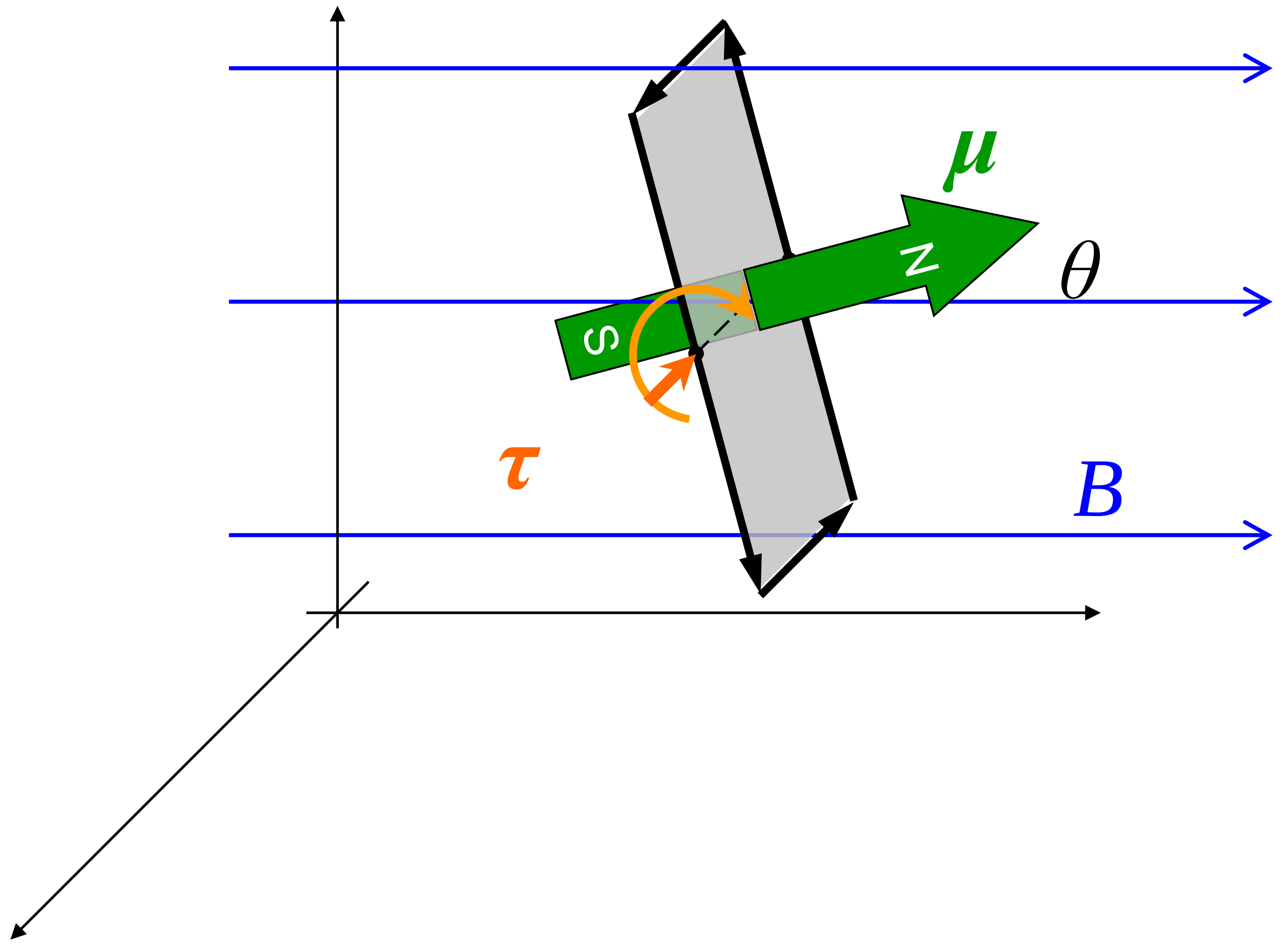
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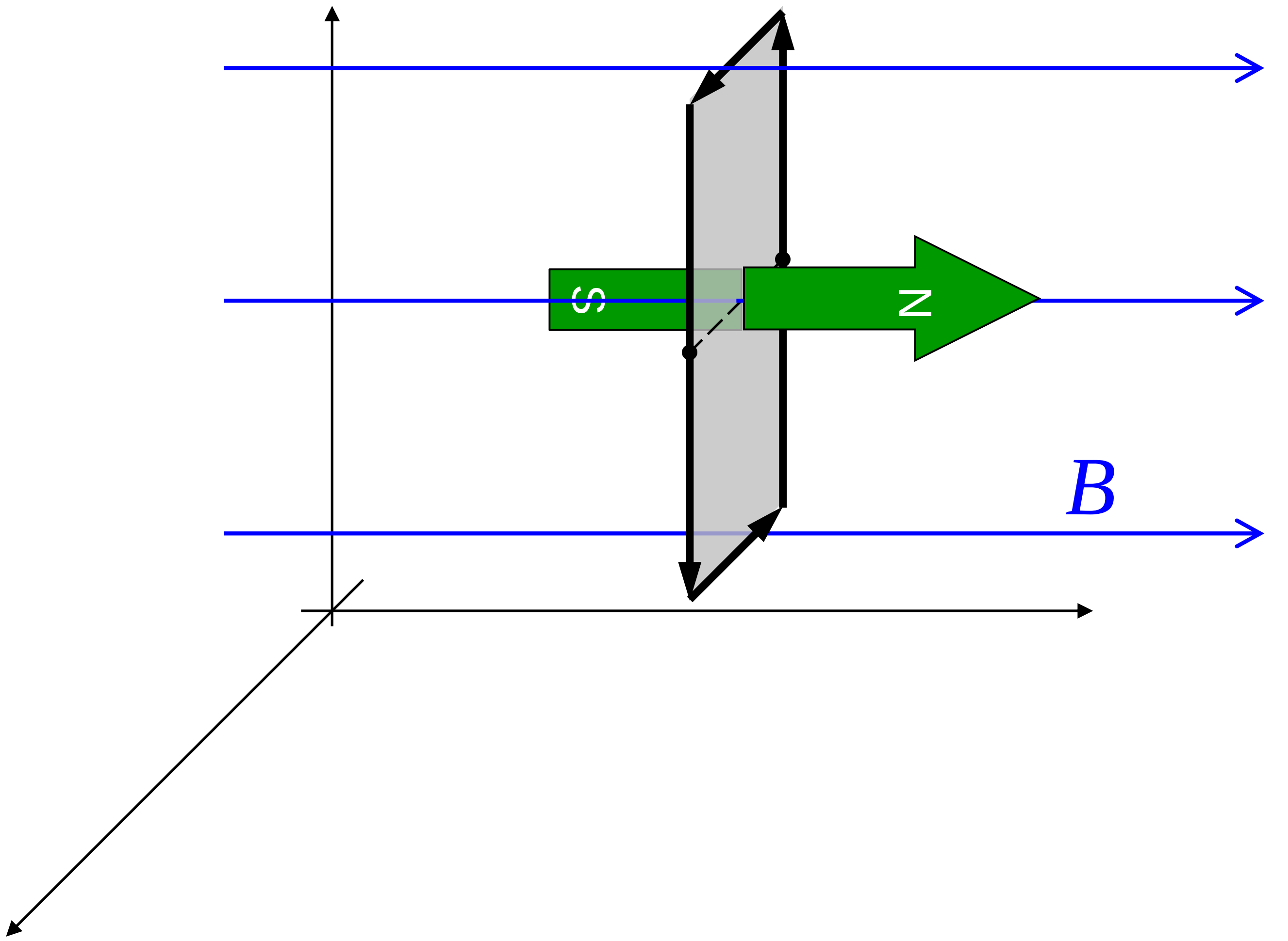
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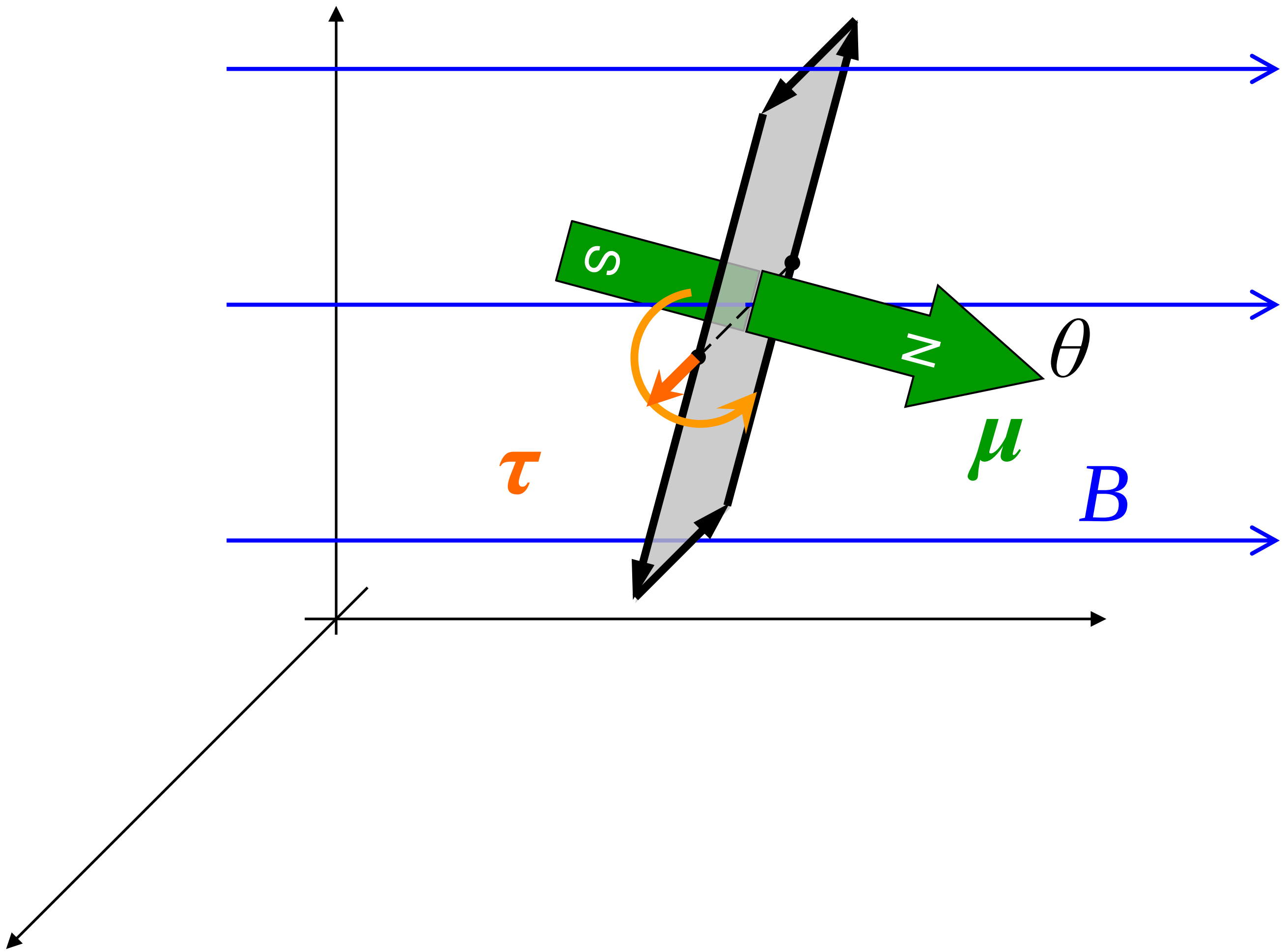
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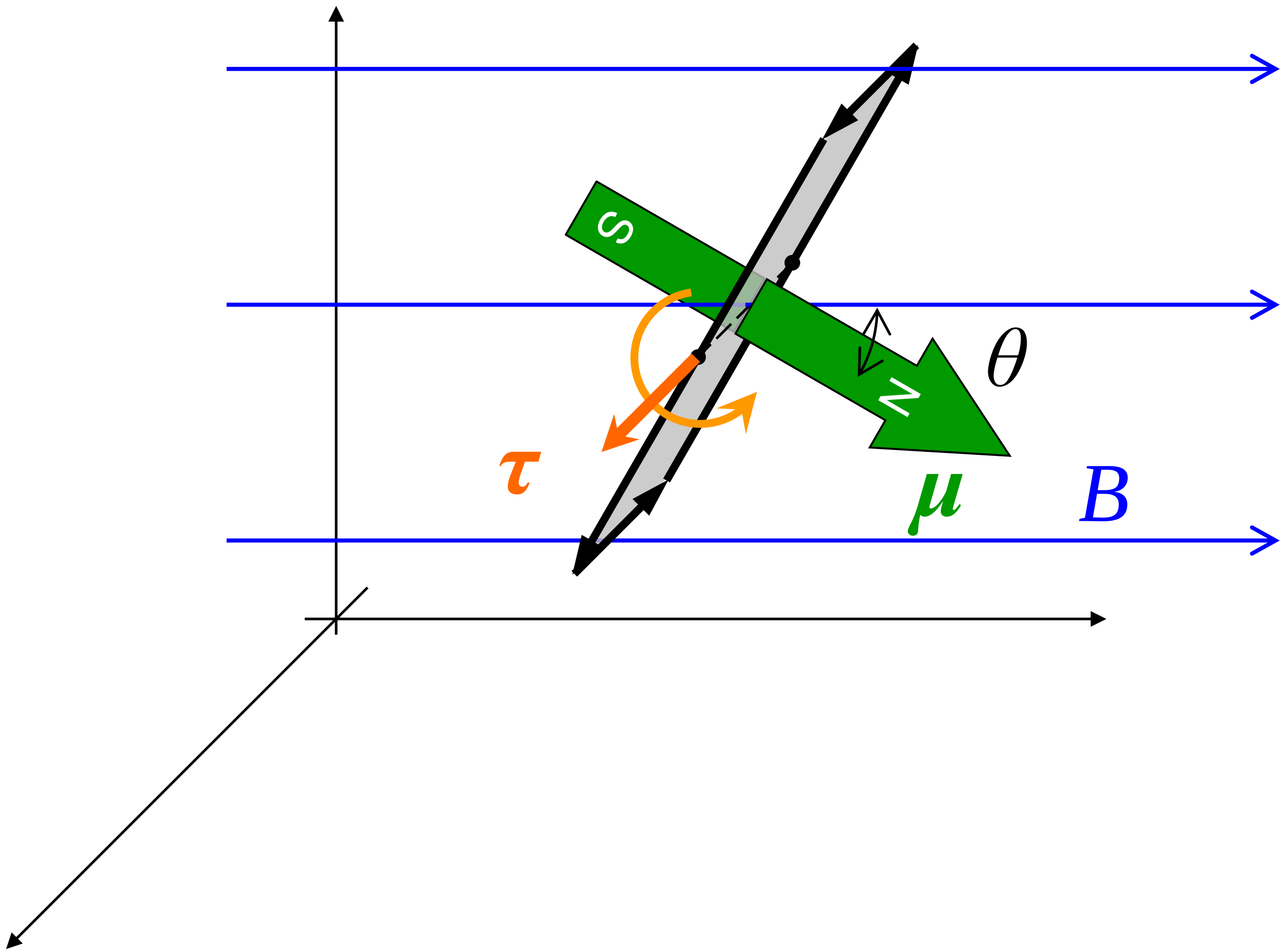
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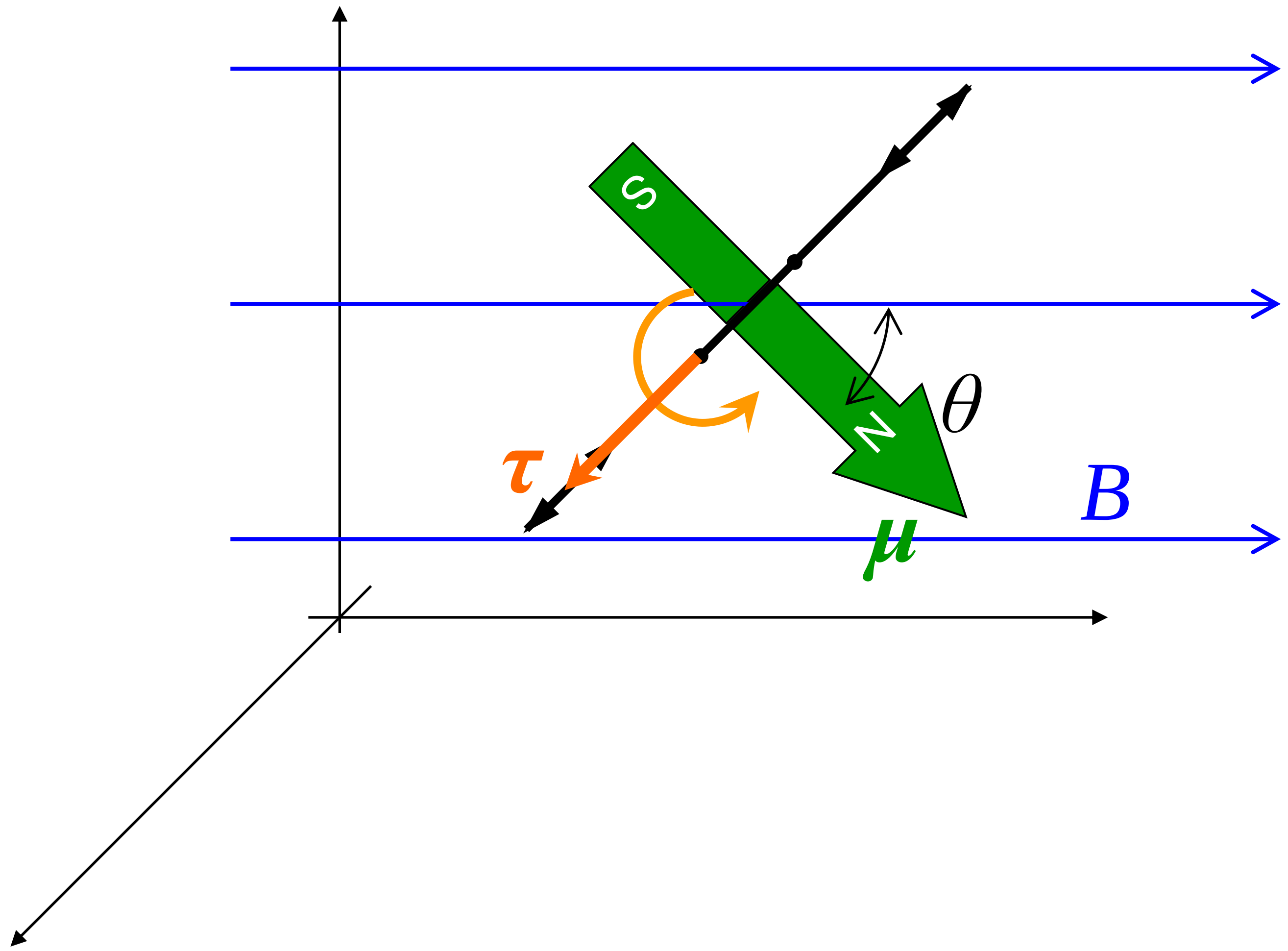
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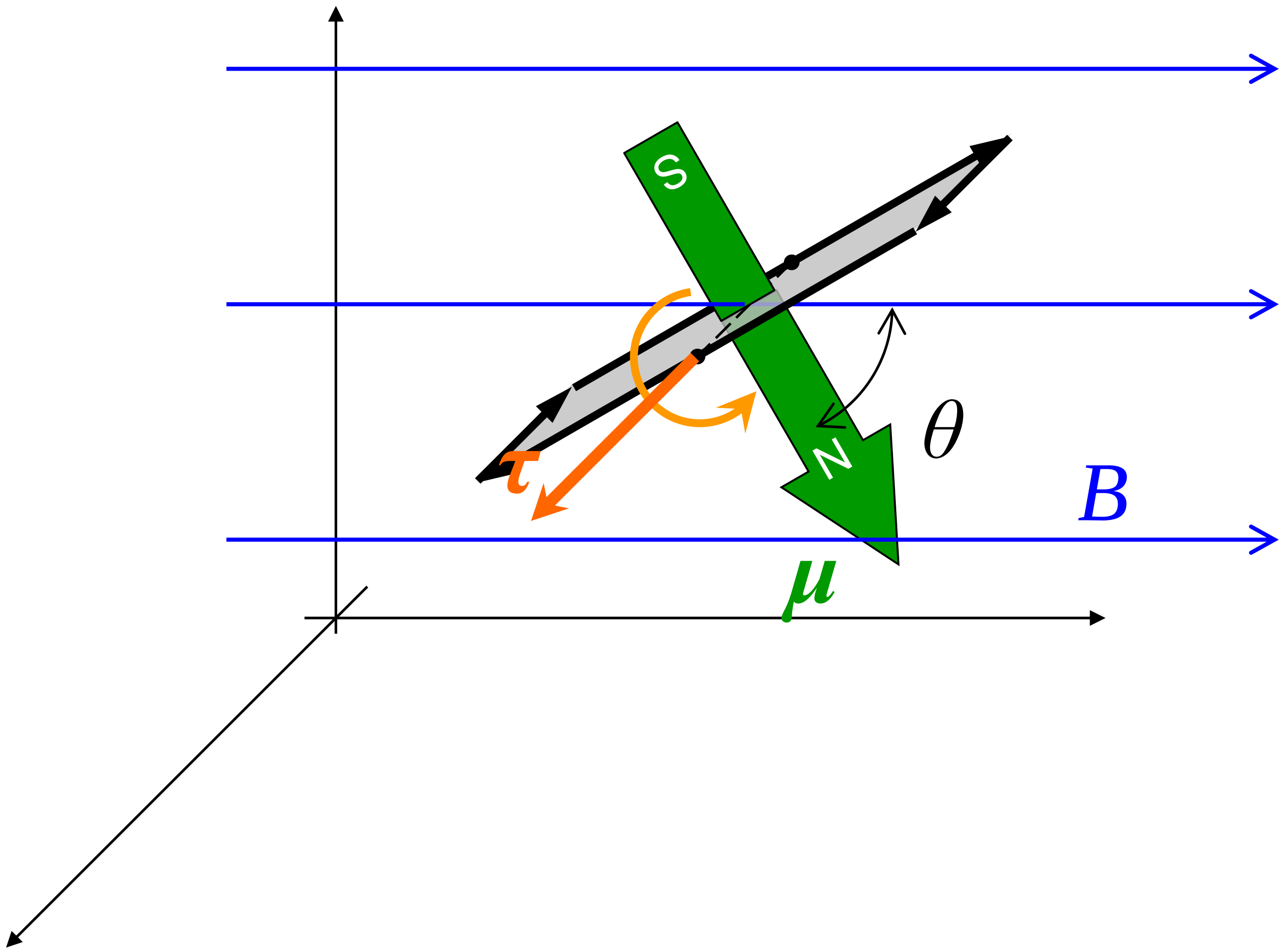
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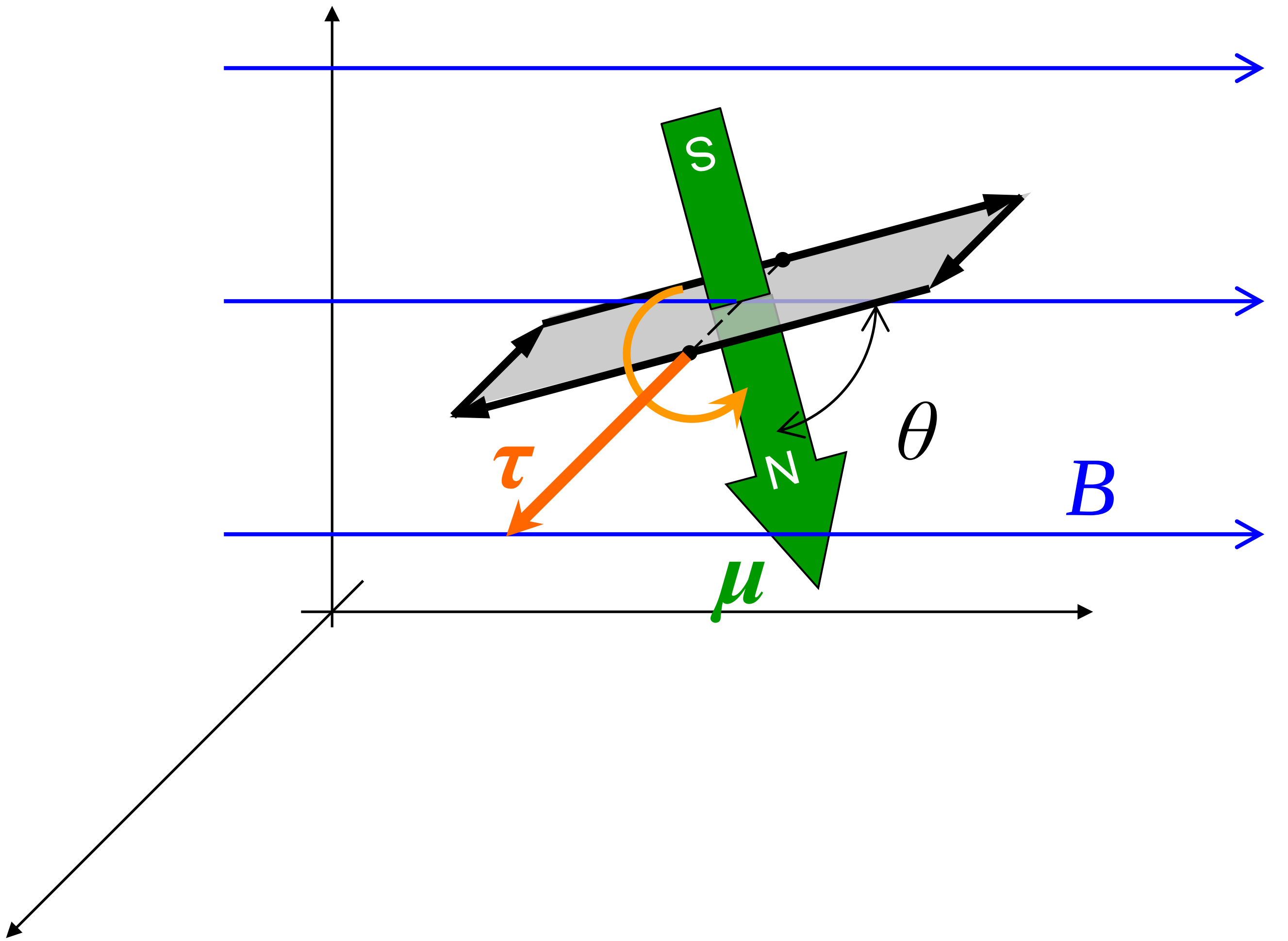
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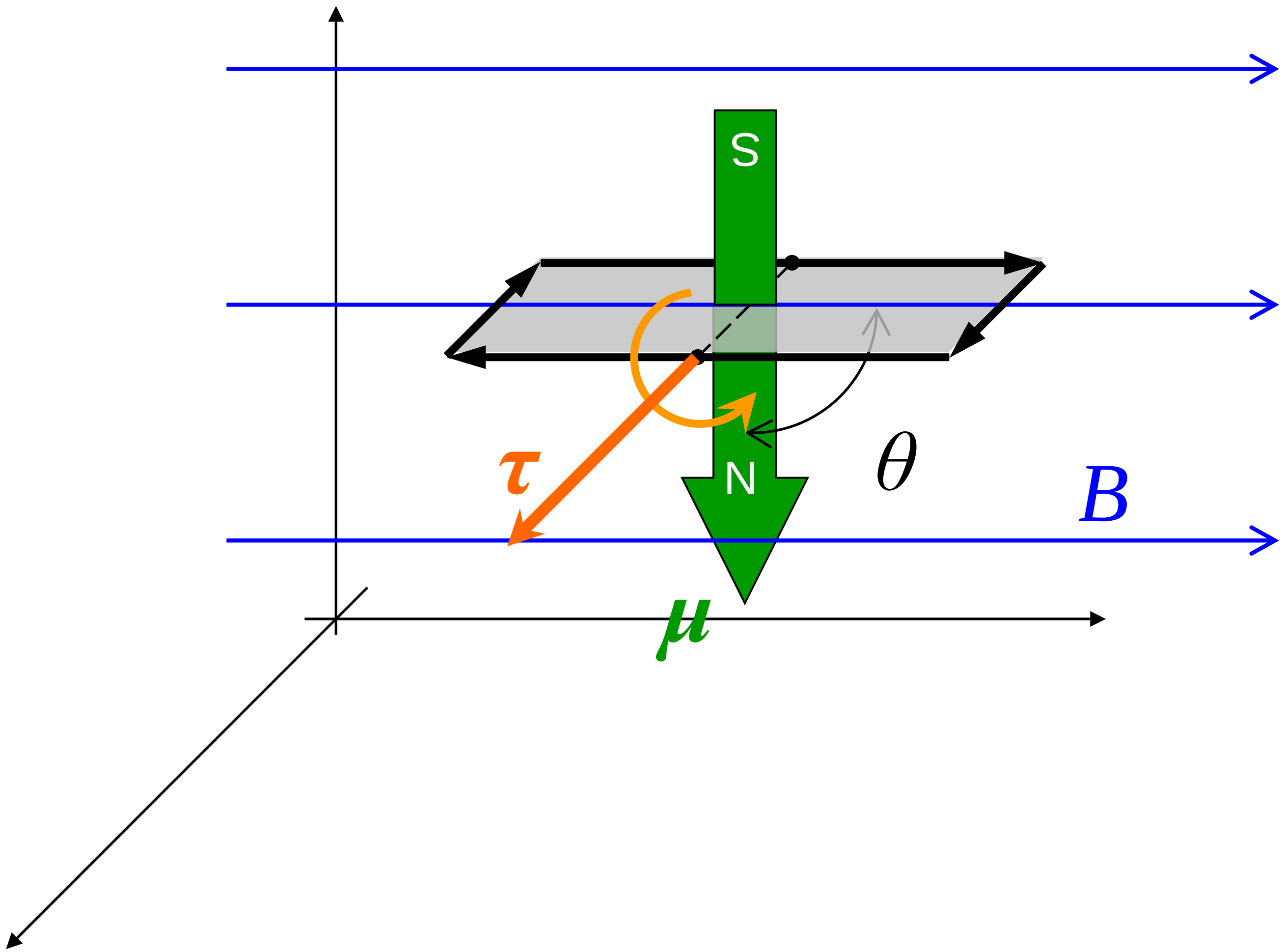

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