Physics

Today's Info Session

- Welcome to this Info Session!
- Introduction
- Physics
  - Electrostatics
  - Magnetism
  - Practice passage
- How Can Next Step Help?
- Questions?

Next Step TEST PREP

MCAT

Medical College Admission Test

WHAT IS YOUR NEXT STEP?

Introduction

Hi, I’m Phil!

- MCAT Content writer
- Tutored and taught for 9+ years
- Attended University of Nebraska Medical Center as an MD/PhD student.

✓ Next Step is a team of test prep and educational experts committed to excellence.

Who Is Next Step?

- Began in 2009 as a tutoring company
- Focus on graduate admissions tests only
- Team of educational experts
- First company to have materials built from ground up for 2015 MCAT format
- Now the first company to have new 2018 MCAT Interface

✓ We never stop improving our materials!

Electrostatics

One of the four fundamental forces of physics:

- Electromagnetism
- Gravity
- Strong Nuclear
- Weak Nuclear

The last two aren't on the MCAT. YAY!

Electrostatics

Difference between electrostatics and magnetism

- **Electrostatics:**

Study of stationary charges

- **Magnetism:**

Moving charges

Electrostatics

Electrostatic Force:

F= kqQ/ r^2

Gravity!

F= GmM/ r^2

Electrostatics

Next Step TEST PREP

Newtons!

Force:

F= kqQ/ r^2

Joules!

Energy:

U= kqQ/ r

Joules = Nm

Energy = Force x distance

Energy = (kqQ/ r^2) (r)

Electrostatics

Newtons!

Force:

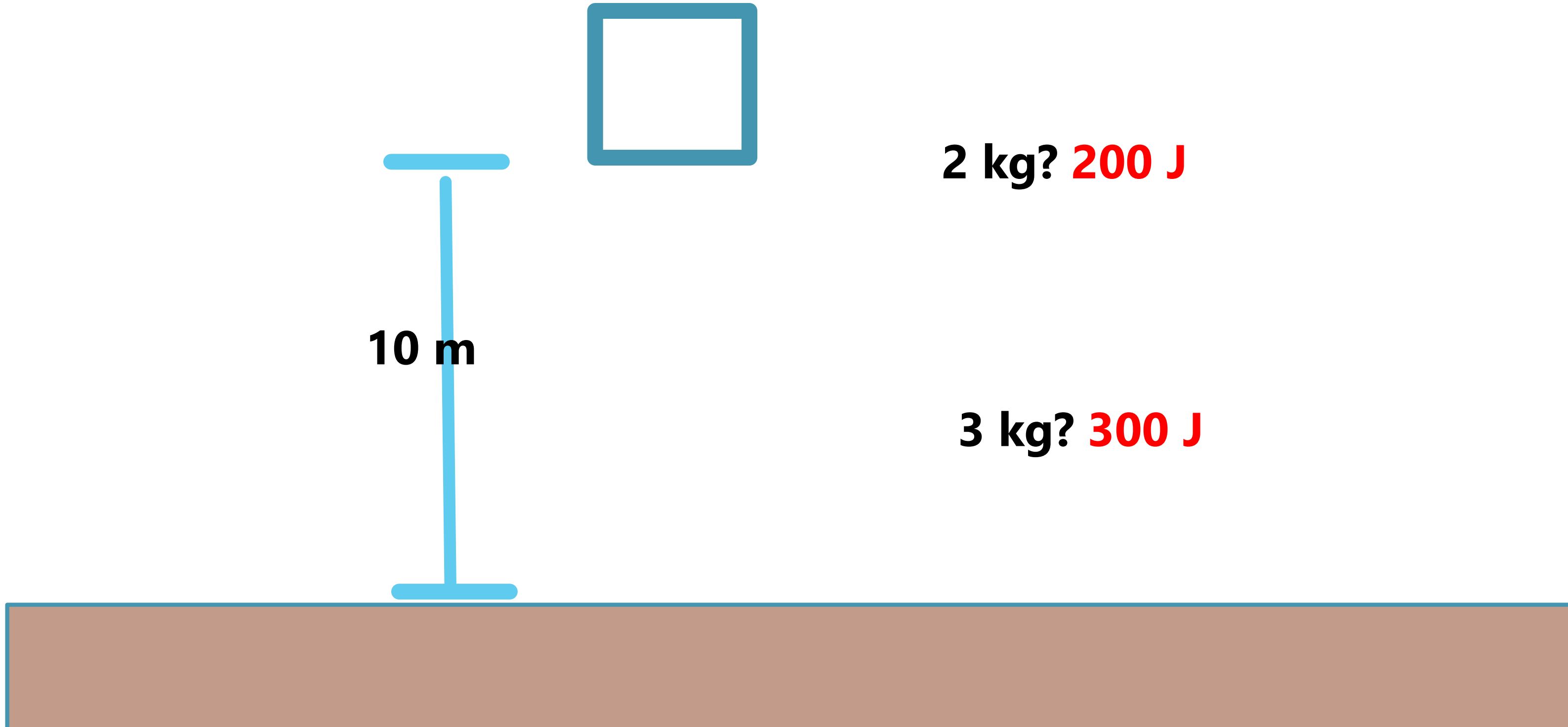
F= kqQ/ r^2

Joules!

Energy:

U= kqQ/ r

This spot is 10 m above the ground, How much energy will a 1 kg object have *if* I put it in the spot? **100 J**



2 kg? **200 J**

3 kg? **300 J**

Electrostatics

Newtons

Force:

F= kqQ/ r^2

Joules

Energy:

U= kqQ/ r

J/C

Potential

V= kq/ r

A single charge will create a voltage. If we put in another charge, it will have energy.

Voltage = Joules/Coulomb

Electrostatics

Newtons

Force:

F= kqQ/ r^2

N/C!

Electric field

E= kq/ r^2

Electric fields are similar to voltage, but are N/C

Joules

Energy:

U= kqQ/ r

J/C

Potential

V= kq/ r

Electrostatics

Force:

$F = kqQ/r^2$

Electric field

$E = kq/r^2$

Energy:

$U = kqQ/r$

Voltage

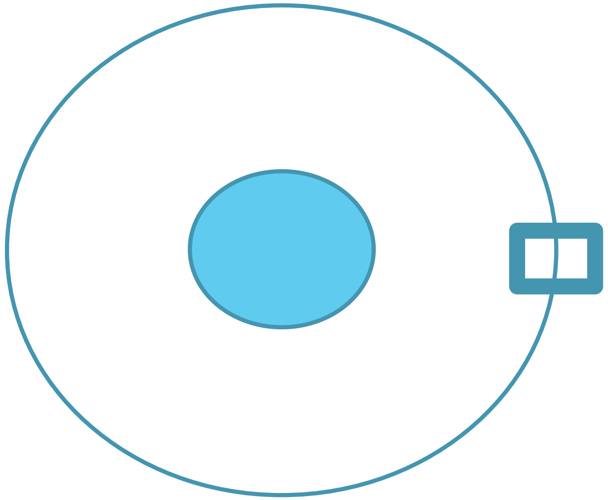
$V = kq/r$

$U = Fr$

$V = Er$

$U = qV$

$F = qE$



2m from a positive charge, there is a voltage of 30 Volts. How much energy will a 2C charge have if I place it there?

$U = qv \rightarrow 30V \times 2\ C = 60\ J$

How much energy if I put a 3C charge at 4m?

At 4m, we have doubled the radius, so the Voltage is cut in half to 15 V.

$U = qV \rightarrow 3C \times 15\ V = 45\ J$

How much force will there be if I place a 6 C charge at 6m?

At 6m, the voltage drops to 10V.
Combining the 2 equations: $U = Fr$ & $U = qv \rightarrow Fr = qV$
$F = qV/r \rightarrow F = (6C)(10V)/(6m) = 10N$

Electrostatics

Force:

F= kqQ/ r^2

Electric field

E= kq/ r^2

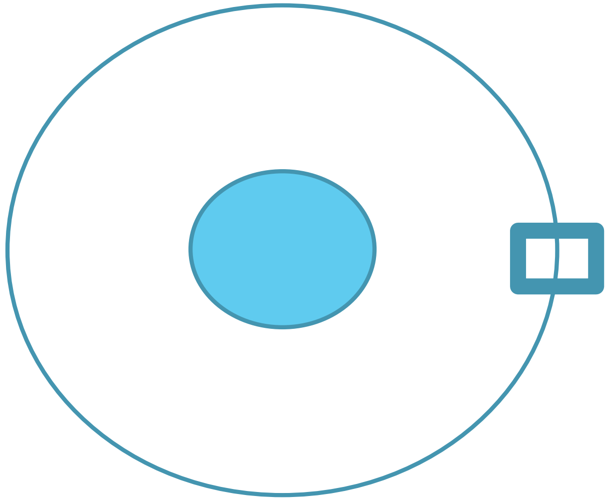
Energy:

U= kqQ/ r

Voltage

V= kq/ r

U= Fr
F=Er
U=qV
F=qE



2m from a positive charge, there is a voltage of 30 Volts.

If I place a 2kg & -2C charge at 6m, how fast will it be going once it reaches 2m?

Using the methods we used before, we see that the charge will have -20J at 6m, and then -60J at 2m.

This means it loses 40J of electrostatic potential energy, but gains 40J of KE.

40 = ½ mv^2 → m is 2, so the equation becomes:

40 = v^2 .

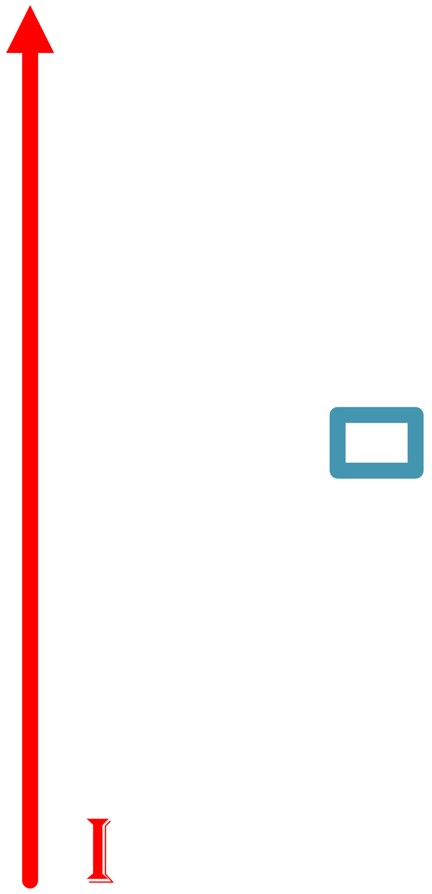
This means it will be going between 6 and 7 m/s.

Magnetism

Magnetic fields are created by moving charges and exert forces on other moving charges.

$$B = \frac{\mu I}{2\pi r}$$

μ = 1.256 x 10^{-6} N/A^2



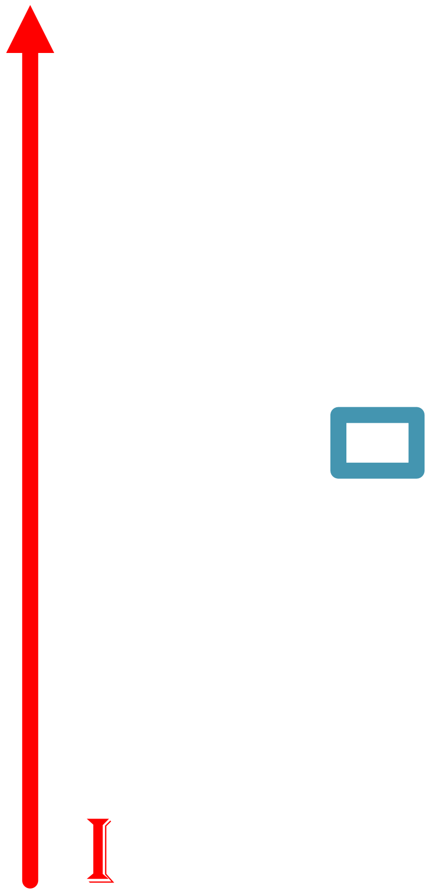
Magnetism

Right-hand-rule #1

Thumb = direction of current

Fingers = curl with magnetic field (which is circular)

Into the page.



Magnetism

Right-hand-rule #1

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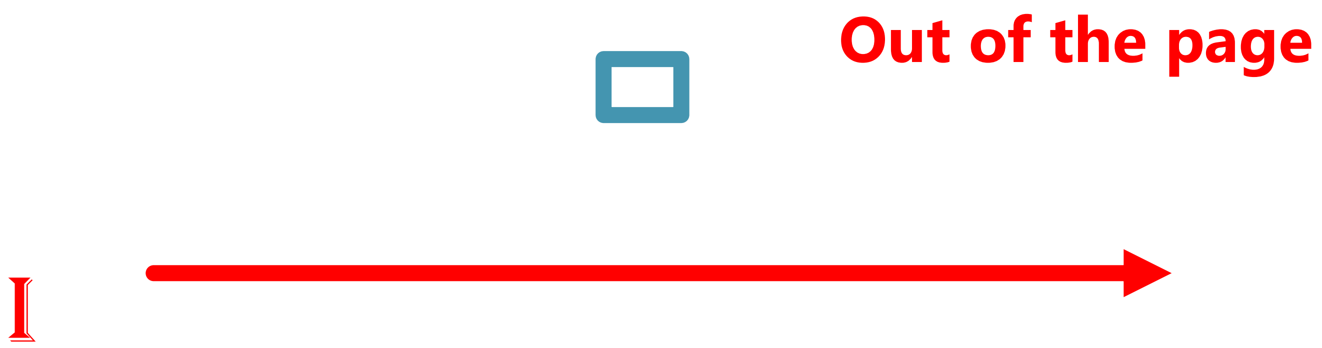


Magnetism

Magnetic fields exert forces on other moving charges. These moving charges could be :

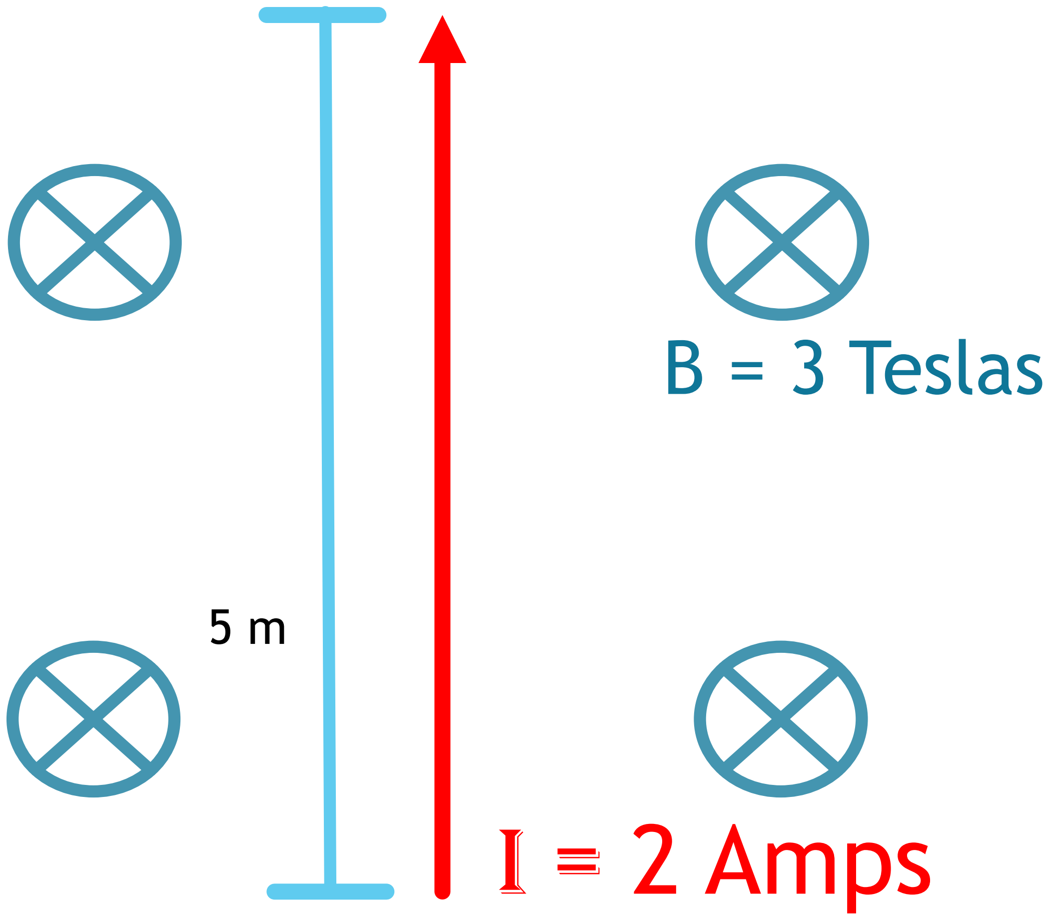
Particles (like a proton)

F = qvBsin theta

Current carrying wires

F = ILBsin theta

For this example, F = 30N



Magnetism

What about direction?

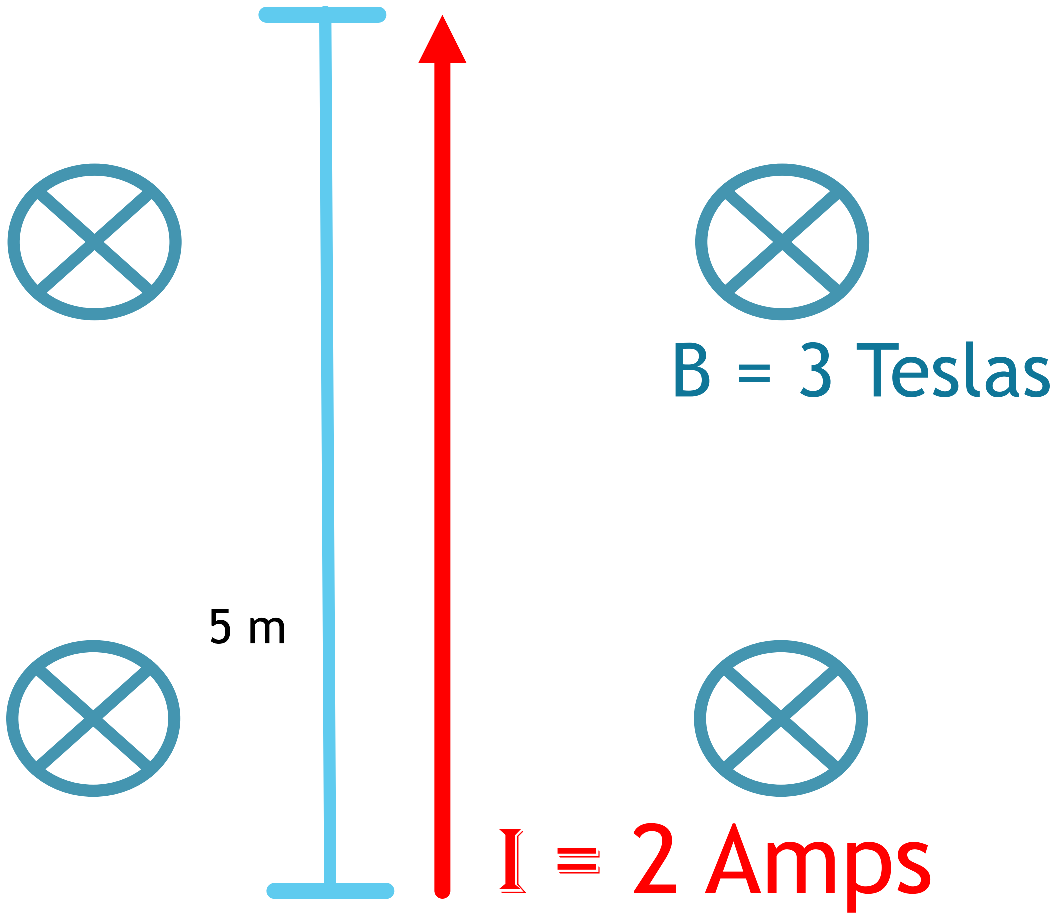
Right-hand-rule #2

Thumb = direction of velocity/ Current

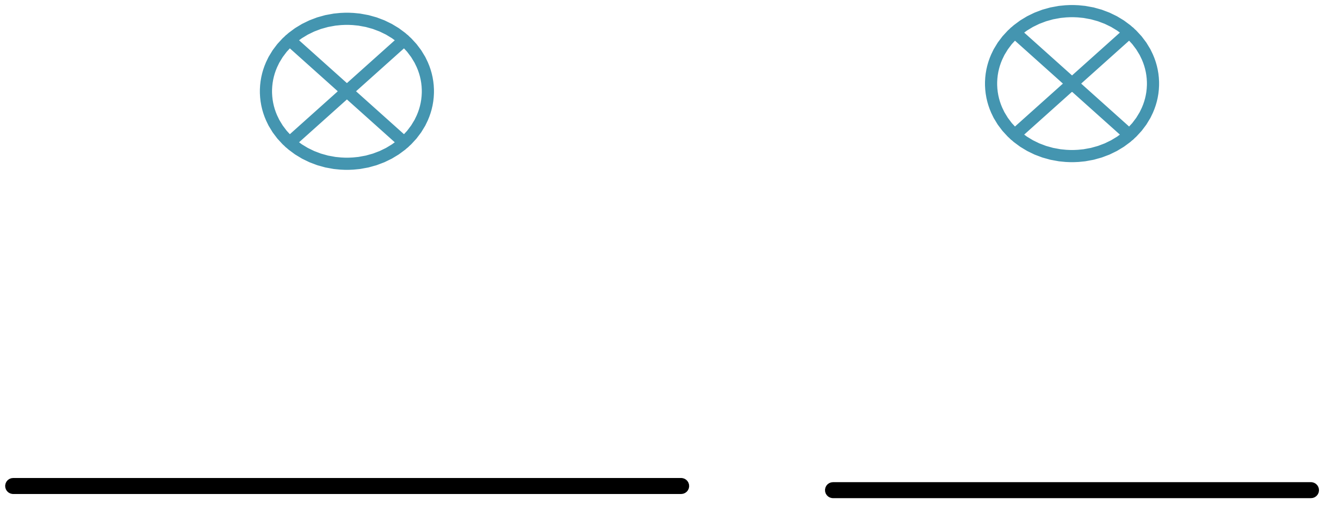
Fingers = direction of B

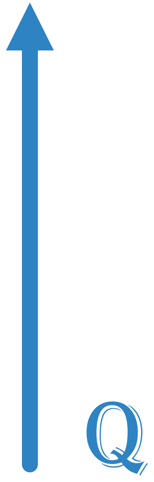
Palm = direction of force

Force will be to the left.



Magnetism





I have a machine that gives molecules a positive charge and then shoots them into a room with a magnetic field at a set speed. What happens as I fire them into the room?

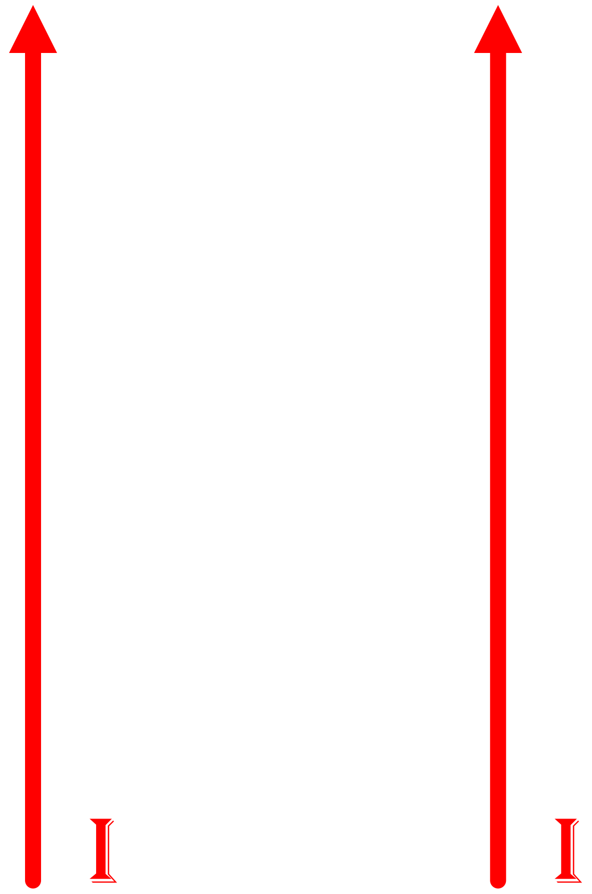
They will curve around to the left and hit the wall.

Heavier molecules are harder to turn, so will hit further away from the hole.

This machine is a mass spec!

Magnetism

When wiring up a power plant, I run two wires in parallel, as shown. Will they exert forces on each other?



They will pull towards each other.

Practice Passage

Action potentials in neurons are often compared to a current-carrying metal wire. Both have electrical current moving in a single directional manner, though the current is caused by electron flow in a wire and positive ion flow in a neuron. When a neuron fires, the current travels down the axon, eventually reaching the axon button and triggering the connection at the synapse.

While magnetic resonance imaging (MRI) is usually used only to look at makeup of tissue, it has been speculated that an MRI machine could be adapted to detect nervous system activity. In the machine, the neuron is subjected to a large magnetic field. As the action potential move across the neuron, the neuron and surrounding tissue will be pulled, due to the presence of the Lorentz force. The direction of the magnetic field (B) generated by the MRI and of the current (I) along the nerve axon are shown in Figure 1. Since the neuron is relatively linear and the magnetic field is strong and constant, the resulting movement could be measured.

Practice Passage

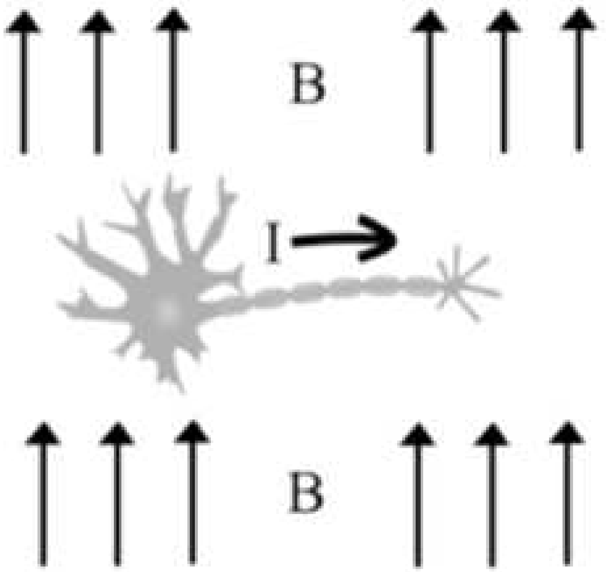


Figure 1 Neuron in a magnetic field (B) generated by an MRI machine

The magnitude of the force on a neuron depends on many factors, including the applied magnetic field and the thickness of the surrounding tissue. Another major factor is the radius of the neuron carrying the action potential, as larger neurons have more moving ions. The magnitude of the Lorentz force, and thus the total displacement of surrounding tissue, is directly proportional to the square of the radius of the neuron.

Adapted from Qian, J., Chen, X., Chen, H., Zeng, L., & Li, X. (2013). Magnetic Field Analysis of Lorentz Motors Using a Novel Segmented Magnetic Equivalent Circuit Method. Sensors (Basel, Switzerland), 13(2), 1664–1678 under CCBY 3.0

Practice Passage

Which of the following devices could be used to directly measure the strength of the action potential in a neuron.

A. An Ammeter

B. A barometer

C. An ohmmeter

D. A voltmeter

A is correct. An ammeter could be used to measure the strength of an action potential. Paragraph 1 notes that neurons are very similar to a current carrying wire, and an ammeter measures current, thus could directly measure the action potential.

B: A barometer measures pressure.

C: An ohmmeter measures resistance.

D: A voltmeter measure potential. While this may indirectly measure the current, more information is necessary to derive this.

Practice Passage

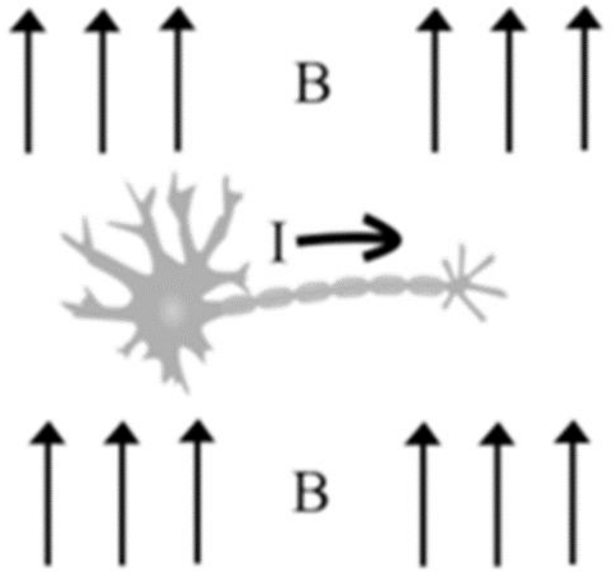
According to the diagram in Figure 1, what is the direction of the force on the neuron as shown?

A. Upwards

B. Out of the page

C. To the right

D. Into the page



B is correct. The force on the neuron will be out of the page. The right hand rule states that with the thumb pointed in the direction of the current and the other fingers in the direction of the magnetic field, the palm will point in the direction of the force on the wire. According to Figure 1, the thumb point right, the other fingers upwards, and the palm points outwards. Only the direction of the current and the magnetic field are necessary to use the right hand rule for the Lorentz force.

Practice Passage

According to the passage, why do researchers believe an MRI machine may be able to detect neuronal activity?

A. Neurons are very thin and thus will show up well on an MRI.

B. Active neurons are denser than dormant ones.

C. Active neurons contain electrical current, thus generating their own magnetic fields.

D. Active neurons contain electrical current and thus are moved by a magnetic field

D is correct. An active neuron contains electric current, is moved by a magnetic field, and thus could be detected by MRI. Paragraph 2 states that the action potential in the neuron generates a force because of the applied magnetic field.

A, B: The thickness of neurons is unrelated to the ability of a magnetic field to exert a force upon moving charges.

C: While a technically true fact, this is not involved in the method being described to detect neuronal activity.

Practice Passage

Compared to an unsheathed neuron, a neuron surrounded with a myelin sheath will:

I. be unable to fire.
II. propagate signals more quickly.
III. have fewer supporting Schwann cells.

A. I only

B. II only

C. I and II

D. II and III

B is correct. A sheathed neuron will propagate signals more quickly than its unsheathed counterpart.

A, C, D: Both unsheathed and sheathed neurons can fire normally. The myelin sheath of the peripheral nervous system is produced by Schwann cells, so they are only around sheathed neurons.

Practice Passage

The researchers involved in prototyping the device described in the passage have found that it can detect neuronal activity in the limbs, but fails to detect brain activity. Which of the following would best explain this observation?

A. Neurons in the brain have thicker lipid membranes than other neurons.

B. Neurons in the brain are twisted, while peripheral neurons tend to be straight.

C. Peripheral neurons generate small currents.

D. Magnetic fields do not interact with currents.

B is correct. Neurons that are straight are required for measurement of the Lorentz force. As stated in paragraph two, a straight neuron produces a current capable of interacting with the magnetic field generated by the MRI machine. A twisted neuron could not do this since the direction of the resulting force would be constantly changing as the direction of the current changes and the detector would be unable to reliably measure this.

A: The thickness of neurons is unrelated to the ability of a magnetic field to exert Lorentz forces upon the neurons being investigated.

C: Current is necessary for the Lorentz force, and for test day we should know that all working nerves must be carrying a current (as the transmit action potentials).

D: Magnetic fields interact with currents to produce the Lorentz force, as stated in paragraph two.

Practice Passage

A positive ion is at rest in a non-polarized aqueous environment. Which of the following best describes the electric field lines in this situation?

A. The field lines point perpendicular to the flow of water.

B. The field lines encircle the ion.

C. The field lines point away from the positive ion.

D. The field lines point away from the positive ion.

C is correct. Electric field lines point away from a positive ion. Electric field lines show the direction a test charge (which is positive) will move within the given electric field. Since positive ions will repel each other, the field lines point directly away from a lone positive ion.

Practice Passage

During an experiment, researchers used an MRI machine to measure a 2 μm displacement in an active ulnar nerve (with a radius of 1 mm and a length of 6 cm). According to the information presented in the passage, what would the displacement due to the Lorentz force on an active median nerve (with a radius of 2 mm and a length of 18 cm) be?

A. 2 μm

B. 4 μm

C. 6 μm

D. 8 μm

D is correct. The displacement due to the Lorentz force will be 8μm. Paragraph three states that the magnitude of the Lorentz force, and thus the displacement, is proportional to the square of the radius of a neuron. The question states that a 1 mm neuron generates a 2 μm displacement. A 2 mm neuron has twice the radius, thus the magnitude of the force will be $2^2 = 4$ times as great. 4(2 μm) = 8 μm

Electricity and Magnetism

$F = kQ_1Q_2 / r^2$

$F = qVB\sin\theta$

$F = iLB\sin\theta$

$V = IR$

$P = IV$

$R = \rho L / A$

$V_{rms} = V_{max} / \sqrt{2}$

$I_{rms} = I_{max} / \sqrt{2}$

Resistors in series:

$R_{tot} = R_1 + R_2 \ldots$

Resistors in parallel:

$1/R_{tot} = 1/R_1 + 1/R_2 \ldots$

Capacitors in series:

$1/C_{tot} = 1/C_1 + 1/C_2 \ldots$

Capacitors in parallel:

$C_{tot} = C_1 + C_2 \ldots$

$C = Q/V$

$\text{Energy} = (1/2)QV$

$F = qE$

$V = Ed$

$\text{Energy} = qEd$

$E = kQ/r^2$

$\text{Energy} = kQq/r$

$V = kQ/r$

$\Delta G = -nFE$

$E_{cell} = E_{cath} - E_{an}$

Waves

$v = f\lambda$

$T = 1/f$

Light

$n_1\sin\theta_1 = n_2\sin\theta_2$

$\sin\theta_c = n_2/n_1$

$E = hf$

$m = -d_i / d_o$

$P = 1/f$

$f = (1/2)r$

$n = c/v$

$1/f = 1/d_i + 1/d_o$

Sound

$d\beta = 10 \log (I/I_o)$

$L = n\lambda/2 \ (n=1, 2\ldots)$

$L = n\lambda/4 \ (n=1,3\ldots)$

$f_{beat} = |f_1 - f_2|$

$f = f_e[v \pm v_d]/[v \pm v_s]$

Fluids

$\rho = m/V$

$P = F/A$

$P = P_{atm} + \rho gd$

$F_b = \rho gV$

$Q = Av$

$P + \rho gy + (1/2)\rho v^2 =$ constant

Gases

$PV = nRT$

Boyle: $PV = k$

Guy-Lussac: $P/T=k$

Charles: $V/T=k$

Avogadro: $n/V=k$

$R_1/R_2 = \sqrt{(m_2/m_1)}$

$P_A = X_A \times P_{tot}$

Solutions

$pH = pK_a + \log (A^-/HA)$

$M = mol / L$

$m = mol / kg$

$N = M \times \#$ of H^+

$pH = -\log [H^+]$

$M_iV_i = M_fV_f$

$\Pi = MRT$

$\Delta T_f = ik_fm$

$\Delta T_b = ik_bm$

$X_A = mol_A / mol_{tot}$

Thermo

$\Delta U = Q - W$

$\Delta U = (3/2)nRT$

$W = P\Delta V$

$Q = mc\Delta T$

$Q = mH_L$

$\Delta G = \Delta H - T\Delta S$

$\Delta H_{rxn} = \Delta H_{prod} - \Delta H_{react}$

Kinematics

$v_f = v_o + at$

$d = v_ot + (1/2)at^2$

$v_f^2 = v_o^2 + 2ad$

$a_c = v^2 / r$

$F_c = mv^2 / r$

$v_x = v_o\cos\theta$

$v_y = v_o\sin\theta$

Mechanics

$F = ma$

$F_{a\ on\ b} = -F_{b\ on\ a}$

$F_{fric} = \mu F_N$

$F_g = GM_1m_2 / r^2$

$F_g = mg$

$F = kx$

$\tau = rF\sin\theta$

$P = W/t$

$W = Fd\cos\theta$

$E_K = (1/2)mv^2$

$U = mgh$

$U = -GM_1m_2 / r$

Inclined Plane

$F_{incline} = mg\sin\theta$

$F_N = mg\cos\theta$

$F_{fric} = \mu mg\cos\theta$

Q&A

Next Step: Core Values

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Approachability

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4.7

Personalized Options

✓ No matter your study style, subject expertise, or MCAT goal, Next Step has an option for your personal needs and lifestyle.

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- **Guided Online Study with Free Extra Help**
- **Flexibility and Personalization**
- **One-on-One Tutoring**

Additional Free Resources

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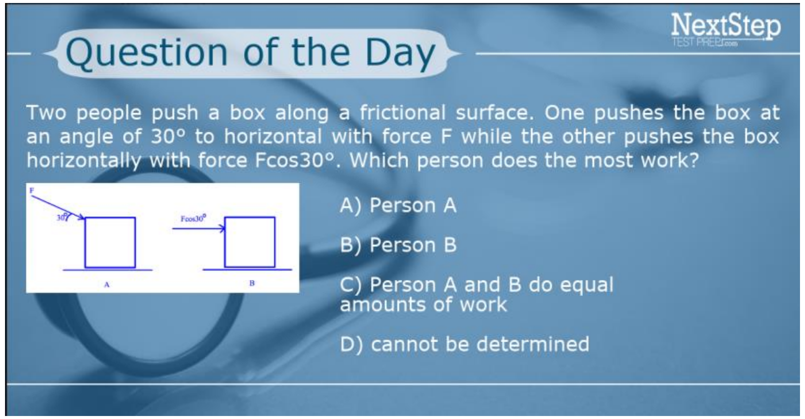
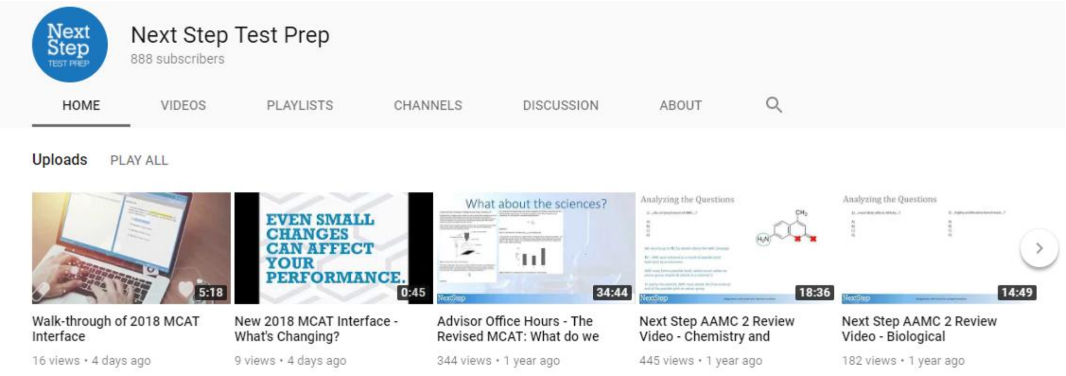
- Next Step MCAT Forum





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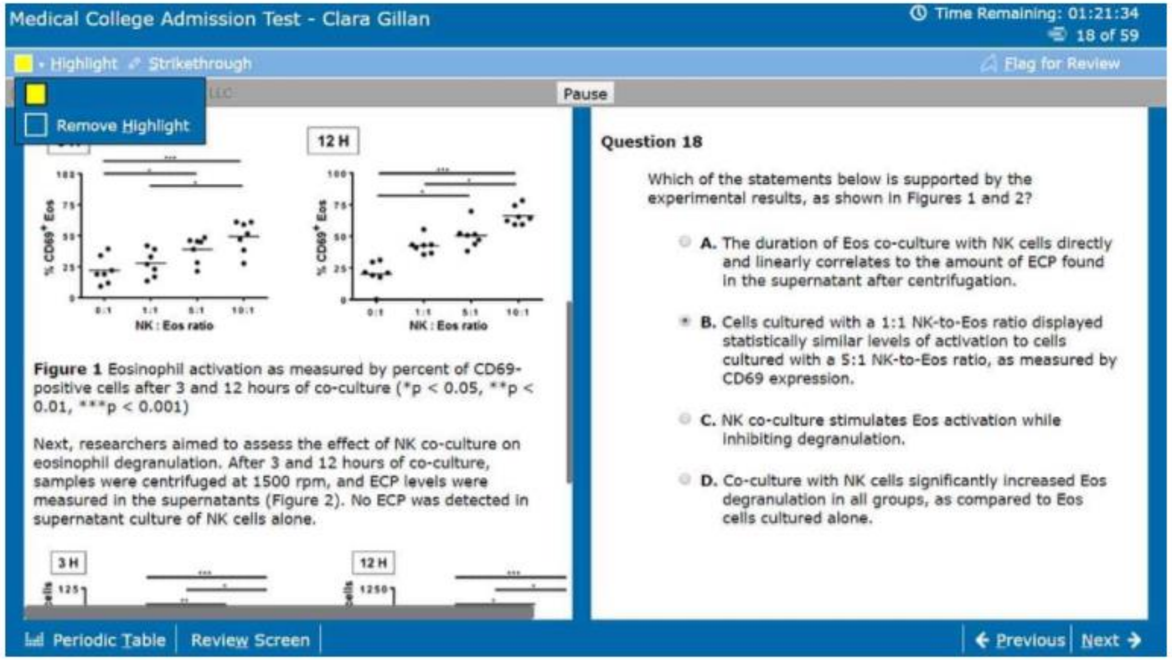

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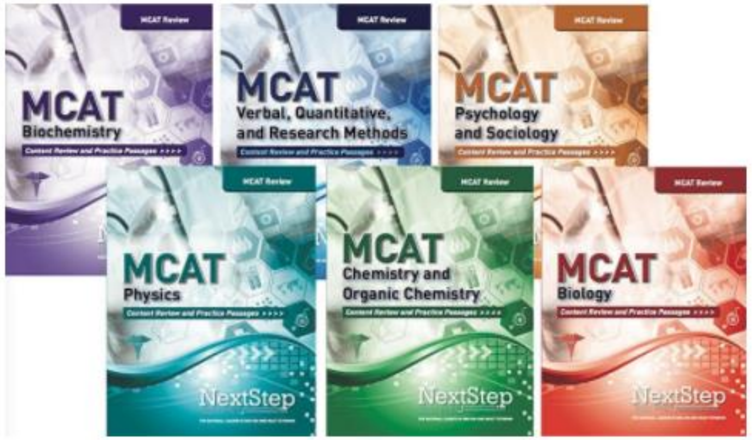

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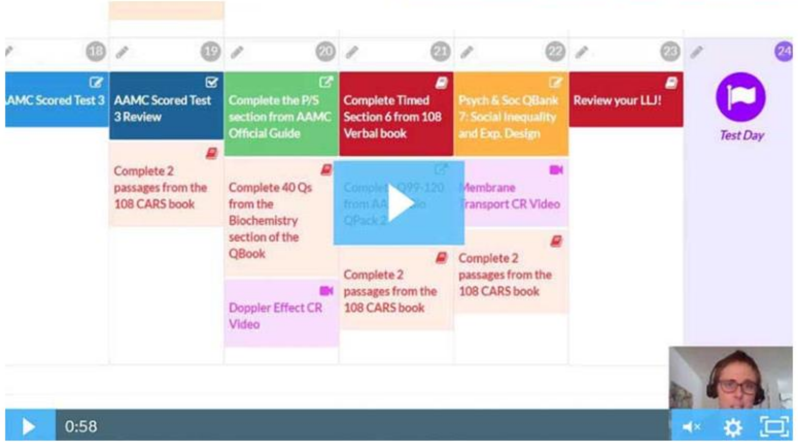

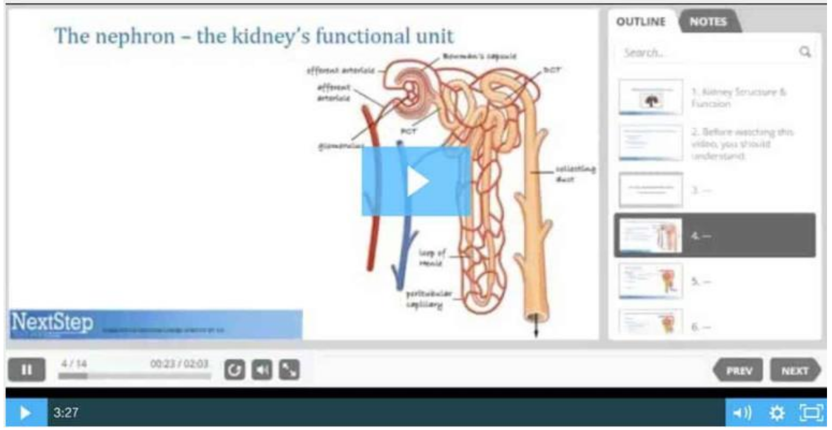

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