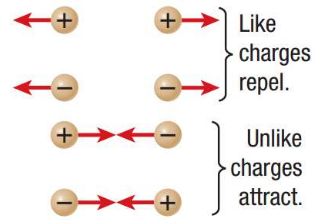
SPH4U 7.1 Properties of Electric Charge

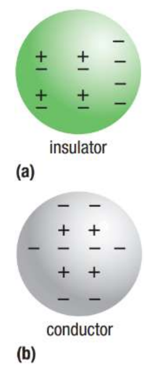
1. Electric charge

Law of electric charges:	
Law of conservation of charge:	
coulomb	



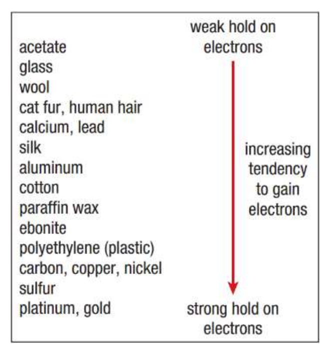
2. Conductors and insulators

Conductor:	
Insulator:	
liquids and gases	
charging an insulator	
charging a conductor	

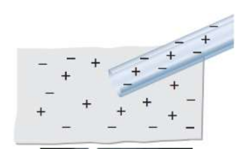


3. Charging objects

By friction:	
electrostatic series	

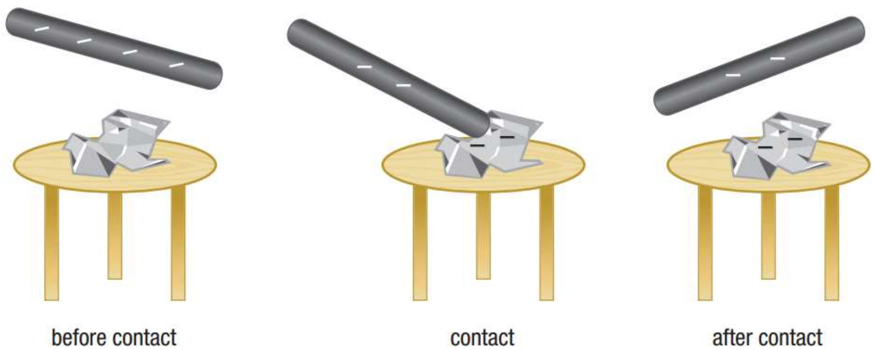


By induced charge separation:	

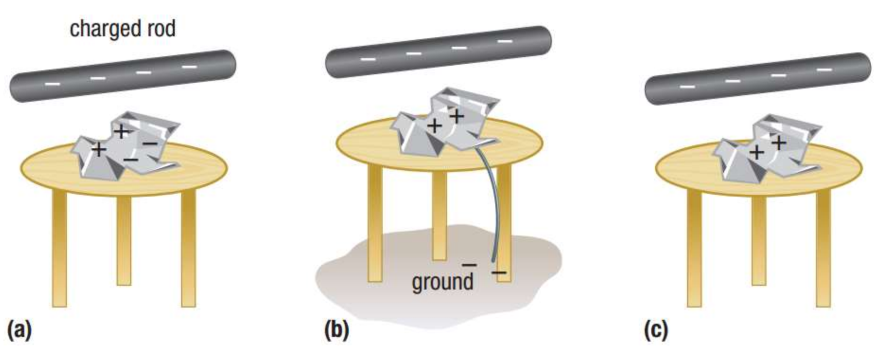


4. Grounding

Grounding:	
Charging by contact:	



Charging by induction:	

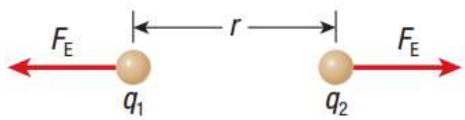


Homework: page 326: #1, 4, 7-9

SPH4U 7.2 Coulomb's Law

1. Electric force

Electric force:	
Coulomb's law:	
Coulomb's constant	
direction	



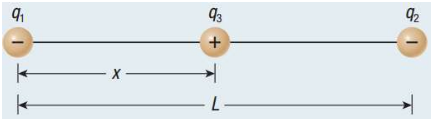
Superposition principal:	

An early model of the hydrogen atom had the electron revolving around the proton, like the Earth revolves around the Sun.

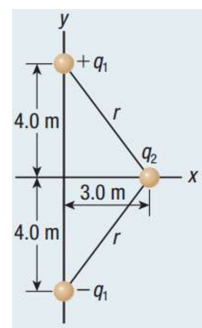
a. The distance between the electron and the proton in a hydrogen atom is 5.3 x 10^{-11} m, the charge of each is 1.6 x 10^{-19} C, the mass of the electron is 9.11 x 10^{-31} kg, and the mass of the proton is 1.67 x 10^{-27} kg. Calculate the ratio of the electric force F_E to the gravitational force F_g.

b. Determine the accelerations of the electron caused by both the electric force and the gravitational force.

Two charges, $q_1 = -2.00 \times 10^{-6}$ C and $q_2 = -1.80 \times 10^{-5}$ C are separated by a distance, L, of 4.00 m. A third charge, $q_3 = +1.50 \times 10^{-6}$ C, is placed somewhere between q_1 and q_2. The net force exerted on q_3 by the other two charges is zero. Determine the location of q_3.



Two point particles have equal but opposite charges of $+q_1$ and $-q_1$. The particles are arranged as shown. Suppose a charge q_2 is placed on the x-axis as shown. $q_1 = 5.0 \times 10^{-6}$ C, $q_2 = 1.0 \times 10^{-6}$ C, and the distance between $+q_1$ and $-q_1$ is 8.0 m measured vertically along the y-axis. Calculate the magnitude and the direction of the net electric force on q_2.

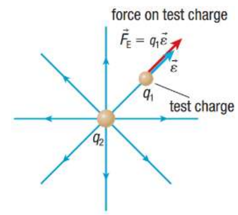


Homework: pg. 333 #1, 5-7, 9b, 10

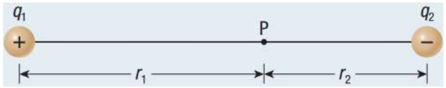
SPH4U 7.3 Electric Fields

1. Electric fields

Electric field:	
equation	
test charge	



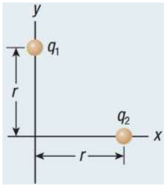
Two point charges are 45 cm apart. The charge on q_1 is 3.3 x 10^{-9} C, and the charge on q_2 is -1.00 x 10^{-8} C.



a. Calculate the net electric field at point P, 27 cm from the positive charge, on the line connecting the charges.

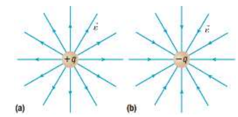
b. A new charge of +2.0 x 10^{-12} C is placed at P. Determine the electric force on this new charge.

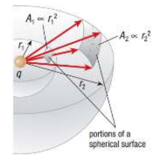
Two point charges are arranged as shown. q_1 = 4.0 x 10^{-6} C, q_2 = -2.0 x 10^{-6} C, and r = 3.0 cm. Calculate the magnitude of the electric field at the origin.



2. Electric field lines

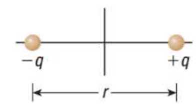
Electric field lines:	
direction	
inverse square law	

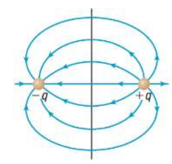


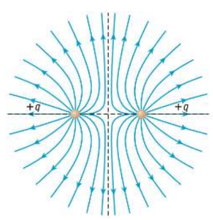


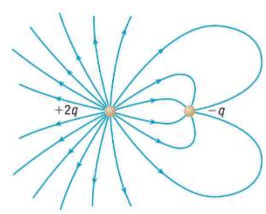
3. Electric dipoles

Electric dipole:	
field lines	
Two +q charges:	
+2q and –q:	

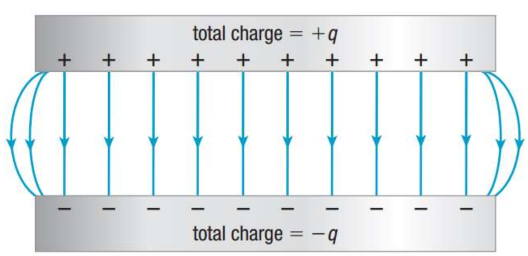








Uniform electric field:	

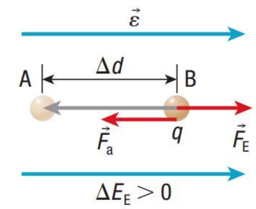


Homework: pg. 345 #2-6

SPH4U 7.4 Potential Difference and Electric Potential

1. Electric potential energy

Electric potential energy:	
equation	
direction	



A charged particle moves from rest in a uniform electric field.

a. For a proton, calculate the change in electric potential energy when the magnitude of the electric field is 250 N/C, the starting position is 2.4 m from the origin, and the final position is 3.9 m from the origin.

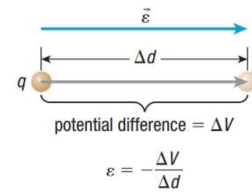
b. Calculate the change in electric potential energy for an electron in the same field and with the same displacement.

c. Using the law of conservation of energy, calculate the final speed of the proton in part (a), assuming that the proton starts from rest.

d. Determine the initial speed of the electron in part (b), assuming its final speed has decreased to half of its initial speed.

2. **Electric potential**

Electric potential:	
equation	
Electric potential difference:	
equation	
uniform electric field	

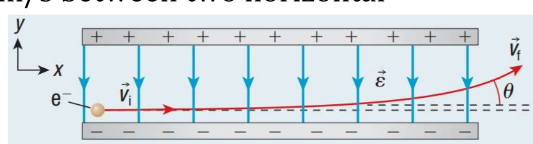


The cathode-ray tubes in old televisions use a uniform electric field to accelerate particles.

a. An electron leaves the negative plate of a cathode-ray tube (CRT) toward the positive plate. The electric potential difference between the plates is 1.5 x 10^4 V. Using conservation of energy, calculate the final speed of the electron, assuming that it is initially at rest. The mass of an electron is 9.11 x 10^{-31} kg.

b. The two plates are 15 cm apart. Calculate the magnitude of the electric field.

An electron moves horizontally with a speed of 1.6 x 10^6 m/s between two horizontal parallel plates. The plates have a length of 12.5 cm. The electric field within the plates is 150 N/C. Calculate the final velcotiy of an electron as it leaves the plates.

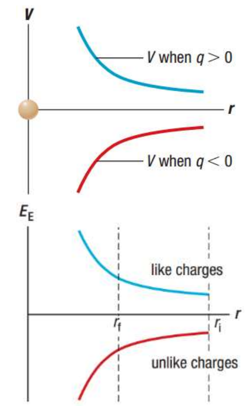


Homework: pg. 354 #1-5, 7

SPH4U 7.5 Electric Potential Due to Point Charges

1. Electric potential due to a point charge

Electric field:	
Electric potential due to a point charge:	
sign	
E_E of two point charges:	
change in E_E	



A point charge with a charge of 4.00×10^{-8} C is 4.00 m due west from a second point charge with a charge of -1.00×10^{-7} C.

a. Calculate the total electric potential due to these charges at a point P, 4.00 m due north of the first charge.

b. Calculate the work required to bring a third point charge with a charge of 2.0×10^{-9} C from infinity to point P.

A point charge q_1 with charge 2.0×10^{-6} C is initially at rest at a distance of 0.25 m from a second charge q_2 with charge 8.0×10^{-6} C and mass 4.0×10^{-9} kg. Charge q_1 remains fixed at the origin, whereas q_2 travels to the right upon release. Determine the speed of charge q_2 when it reaches a distance of 0.50 m from q_1.

2. **Head-on "collision"**

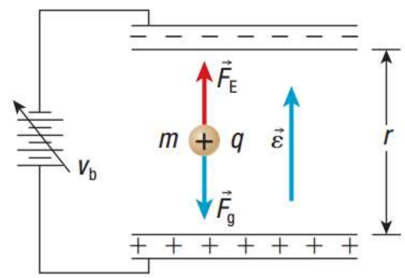
Two particles, a proton with charge 1.60×10^{-19} C and mass 1.67×10^{-27} kg and an alpha particle (He-4 nucleus) with charge 3.20×10^{-19} C and mass 6.64×10^{-27} kg, are separated by an extremely large distance. They approach each other along a straight line with initial speeds of 3.00×10^{6} m/s each. Calculate the separation between the particles when they are closest to each other.

Homework: pg. 361 #1-4, 6, 8

SPH4U 7.6 The Millikan Oil Drop Experiment

1. Millikan's experiment

Fundamental physical constants:	
Elementary charge:	
Millikan's experiment	



Electric charge:	
excess protons	

Calculate the charge on a small sphere with an excess of 3.2 x 10^{14} electrons.

In a Millikan-type experiment, two horizontal plates aintained at a potential difference of 360 V are separated by 2.5 cm. A latex sphere with a mass of 1.41 x 10^{-15} kg hangs between the plates, the upper plate of which is positive.

a. Is the sphere negatively or positively charged?

b. Calculate the magnitude of the charge on the latex sphere.

c. Determine the number of excess of deficit particles on the sphere.

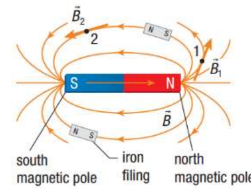
Quarks:	
subatomic particles	

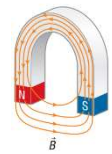
Homework: pg. 365 #1-3, 5-7

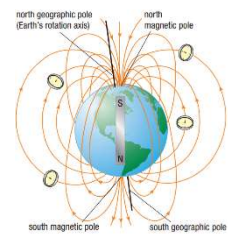
SPH4U 8.1 Magnets and Electromagnets

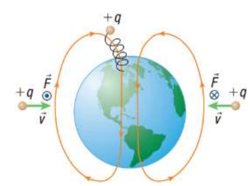
5. Permanent magnets

Magnetic field:	
magnetic field lines	
magnetic poles	
Earth's magnetic field:	
causes	
compass	
cosmic rays	







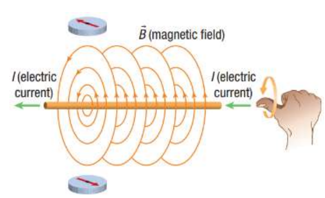


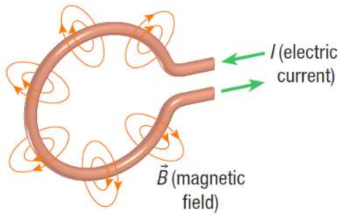
6. Electromagnetism

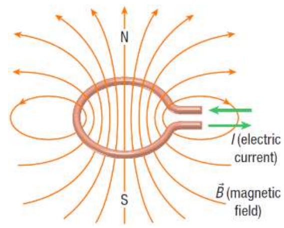
Principle of electromagnetism:	
Right-hand rule for a straight conductor:	

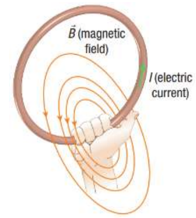
Right-Hand Rule for a Straight Conductor

If your right thumb is pointing in the direction of conventional current, and you curl your fingers forward, your curled fingers point in the direction of the magnetic field lines.





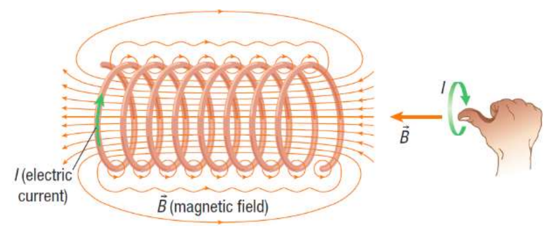




Current loop:	
Solenoid:	
Right-hand rule for a solenoid:	

Right-Hand Rule for a Solenoid

If you coil the fingers of your right hand around a solenoid in the direction of the conventional current, your thumb points in the direction of the magnetic field lines in the centre of the coil.



Electromagnet:	
factors	
applications	

Homework: pg. 385 #1-3, 5

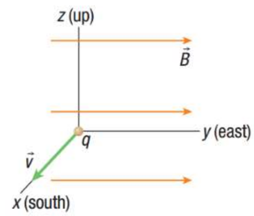
SPH4U 8.2 Magnetic Force on Moving Charges

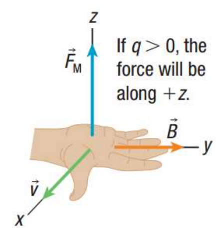
7. Magnetic force

Magnetic field strength:	
Magnetic force:	
equation	
direction	

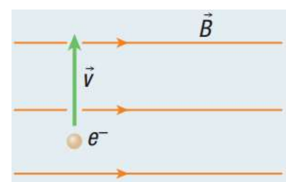
Right-Hand Rule for a Moving Charge in a Magnetic Field

If you point your right thumb in the direction of the velocity of the charge ($\vec{v}$), and your straight fingers in the direction of the magnetic field ($\vec{B}$), then your palm will point in the direction of the resulting magnetic force ($\vec{F}_M$).





The electron shown moves at a sped of 54 m/s through a magnetic field with a strength of 1.2 T. The angle between the electron's velocity and the magnetic field is 90°. Assume the electron's charge is $-e = -1.60 \times 10^{-19}$ C.



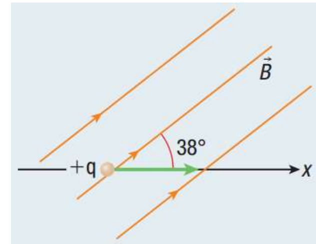
a. What is the magnitude of the magnetic force on the electron?

b. Use the right-hand rule to determine the direction of the magnetic force.

c. Calculate the gravitational force on the electron ($m = 9.11 \times 10^{-31}$ kg).

d. What is the ratio of gravitational force to magnetic force on the electron?

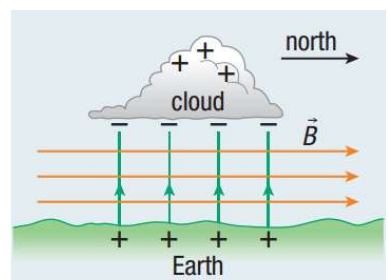
A proton is moving along the x-axis at a speed of 78 m/s. It enters a magnetic field of strength 2.7 T. The angle between the proton's velocity and the magnetic field is 38°. The mass of a proton is 1.67 x 10^{-27} kg.



a. Calculate the initial magnitude and direction of the magnetic force on the proton.

b. Determine the proton's initial acceleration.

During a thunderstorm, positive charge accumulates near the top of a cloud, and negative charge accumulates near the bottom. When the charge buildup is strong enough, negative charge moves rapidly from the cloud to the ground, as a lightning strike. Assume the charge is moving perpendicular to the ground, and Earth's magnetic field is horizontal, directed north. Determine the direction of the deflection of this charge by Earth's magnetic field.

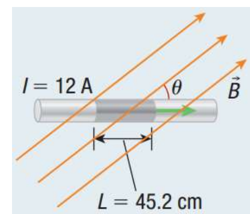


Homework: pg. 391 #1-3, 5-6, 8, 10

<u>SPH4U 8.3 Magnetic Force on a Current-Carrying Conductor</u>

8. Magnetic force and current

Electric current:	
single charge	
wire with current	
direction	



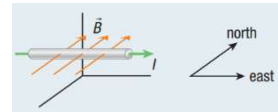
A piece of wire 45.2 cm long has a current of 12 A. The wire moves through a uniform magnetic field with a strength of 0.30 T. Calculate the magnitude of the magnetic force on the wire when the angle between the magnetic field and the wire is:

a. 0°

b. 45°

c. 90°

Two electrical poles support a current-carrying wire. The mass of a 2.5 m segment of the wire is 0.44 kg, and a 15 A current travels through it. The convential current is due east, horizontal to Earth's surface. Earth's magnetic field is 57 μT and is oriented due north, horizontal to Earth's surface.

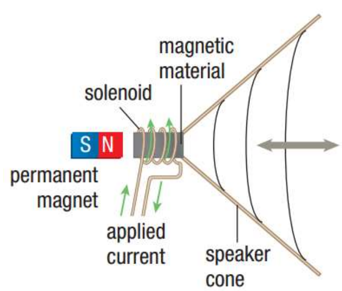


a. Determine the magnitude and direction of the magnetic force on the 2.5 m segment of wire.

b. Calculate the gravitational force on the 2.5 m segment of wire.

9. Applications

Loudspeakers:	

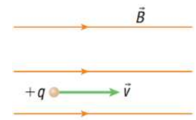


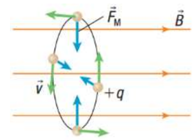
Homework: pg. 396 #1, 3-5

SPH4U 8.4 Motion of Charged Particles in Magnetic Fields

10. Uniform circular motion of charges

Moving parallel to $\vec{B}$:	
Moving perpendicular to $\vec{B}$:	
result	
centripetal force	
equation	





An electron (m = 9.11 x 10^{-31} kg) starts from rest. A horizontally directed electric field accelerates the electron through a potential difference of 37 V. The electron then leaves the electric field and moves into a magnetic field with strength 0.26 T, directed into the page.

a. Determine the speed of the electron at the moment it enters the magnetic field.

b. Determine the magnitude and direction of the magnetic force on the electron.

c. Determine the radius of the electron's circular path.

11. Mass spectrometer

Mass spectrometer:	

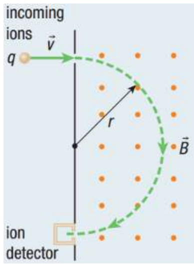
A researcher using a mass spectrometer observes a particle travelling at 1.6 x 10^6 m/s in a circular path of radius 8.2 cm. The spectrometer's magnetic field is perpendicular to the particle's path and has a magnitude of 0.41 T.

a. Calculate the mass-to-charge ratio of the particle.

b. Identify the particle using the table provided.

Isotope	m (kg)	q (C)	$\frac{m}{q}$ (kg/C)
hydrogen	1.67×10^{-27}	1.60×10^{-19}	1.04×10^{-8}
deuterium	3.35×10^{-27}	1.60×10^{-19}	2.09×10^{-8}
tritium	5.01×10^{-27}	1.60×10^{-19}	3.13×10^{-8}

A researcher uses a mass spectrometer in a carbon dating experiment. The incoming ions are a mixture of $^{12}C^+$ and $^{14}C^+$, and they have speed v = 1.0 x 10^5 m/s. The strength of the magnetic field is 0.10 T. The mass of an electron is 9.11 x 10^{-31} kg, and the mass of protons and neutrons is 1.67 x 10^{-27} kg.



The researcher first positions the ion detector to determine the value of r for $^{12}C^+$, then moves it to determine the value of r for $^{14}C^+$. How far must the detector move between detecting the two isotopes?

Homework: pg. 404 #2-3, 5-6