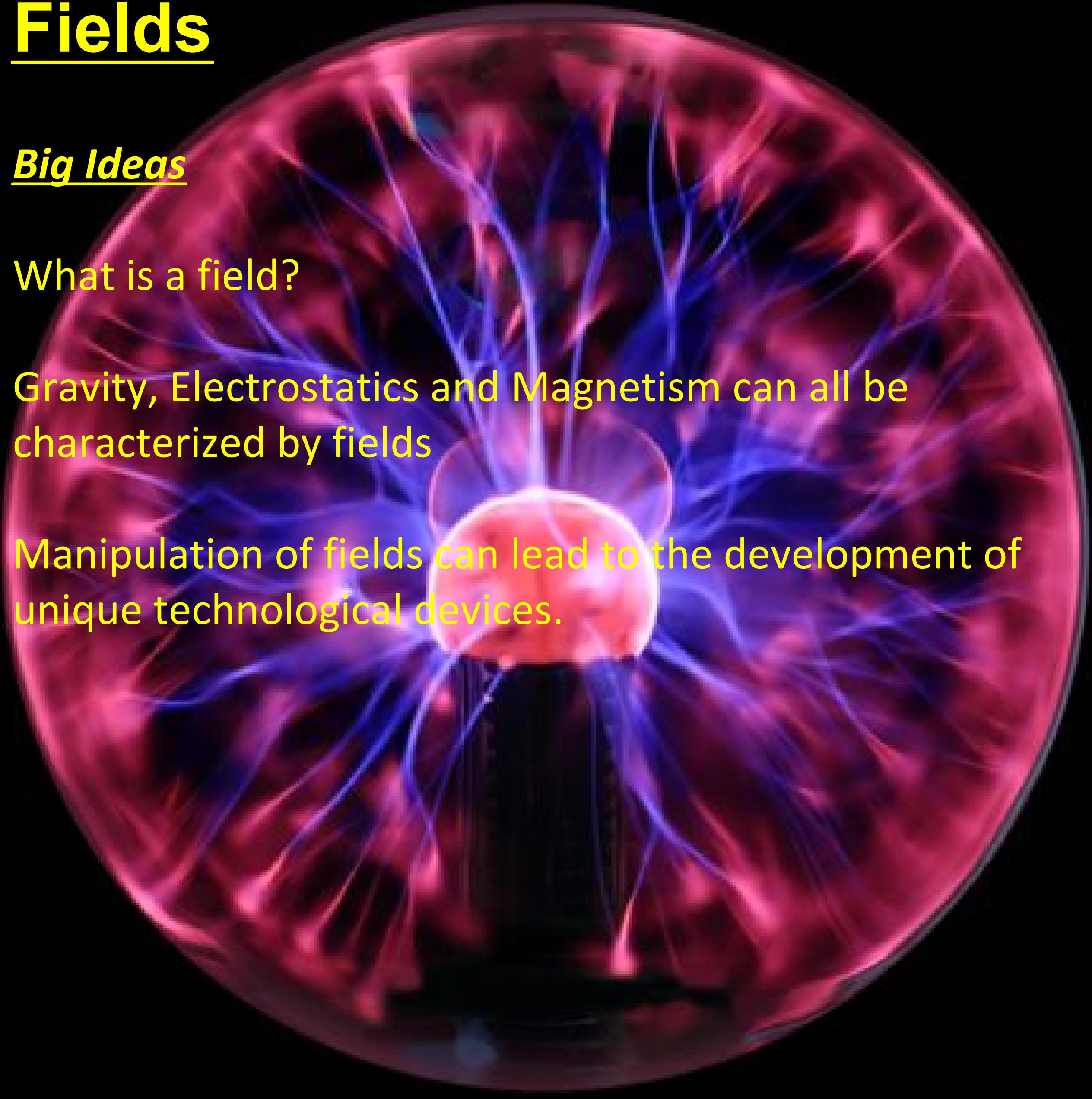
Fields



Big Ideas

What is a field?

Gravity, Electrostatics and Magnetism can all be characterized by fields

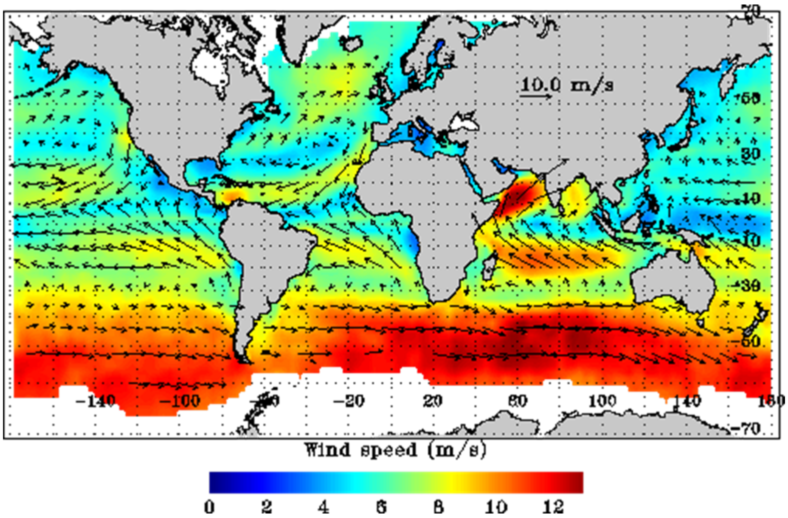
Manipulation of fields can lead to the development of unique technological devices.

Outline
1. Definition and Examples of Fields
2. Gravitational Fields
3. Electric Forces and Fields
4. Sample Problems

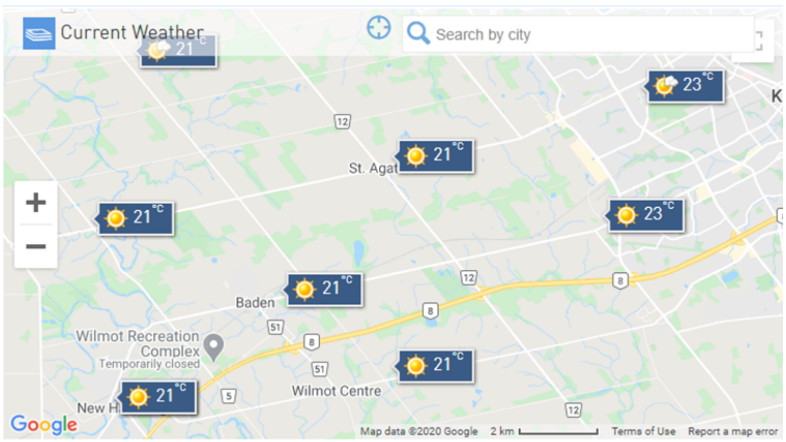
1. What is a Field ?

A field is something that has a well defined value at every point in space. Scalar fields have only a magnitude at every point. Vector fields also have a direction at every point.

Examples of Fields

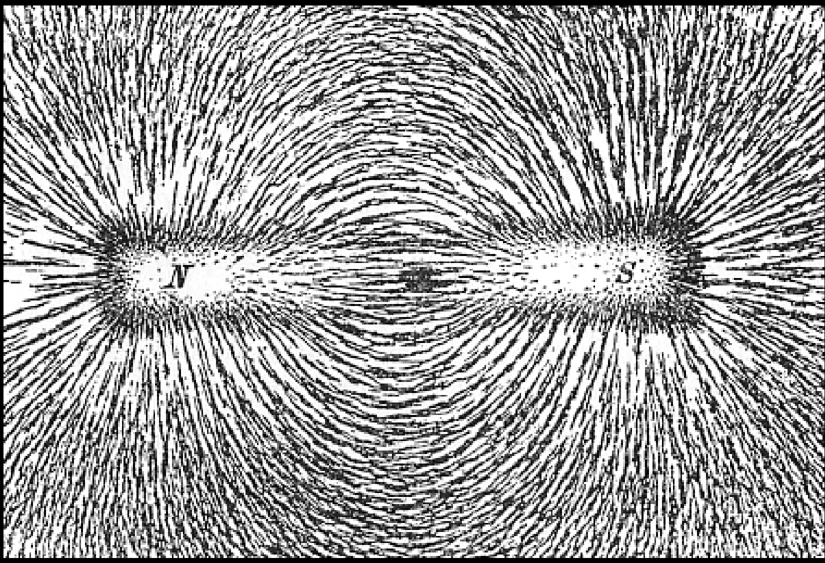


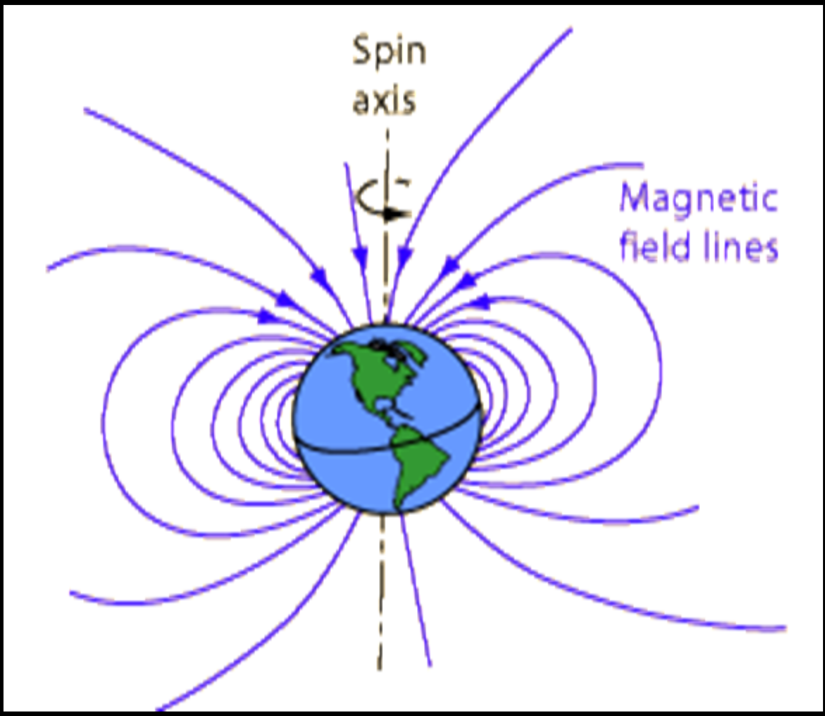
Wind Velocity - Vector Field



Temperature - Scalar Field

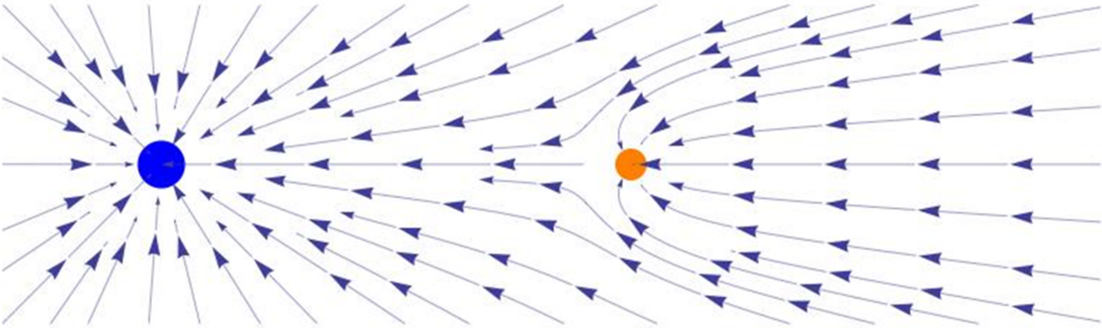
Examples of Fields - cont'd



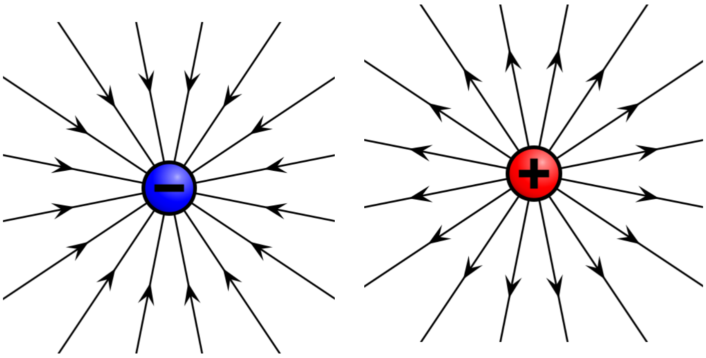


Magnetic Field - Vector Field

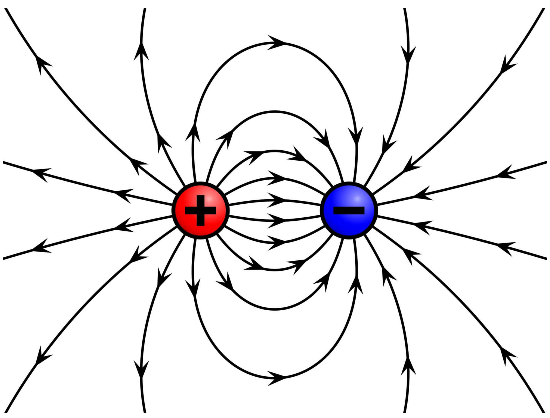
Examples of Fields - cont'd

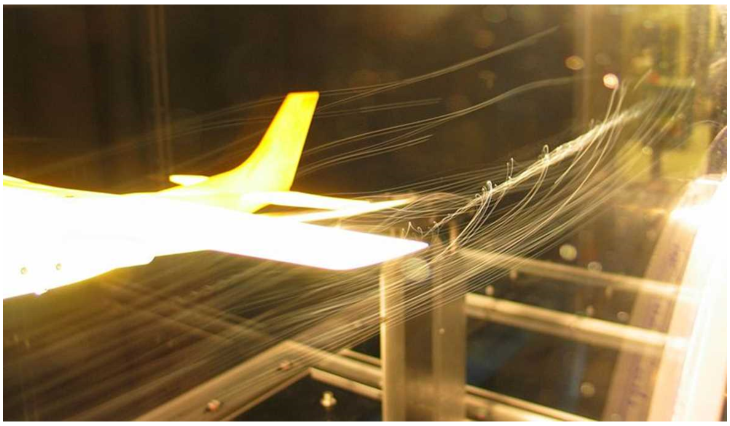


Gravitational Field - Vector Field



Electric Field - Vector Field





Turbulent Air Flow - Vector Field

On line vector field visualization resources

http://kevinmehall.net/p/equationexplorer/index.html#y=1/x%5E2%7C%5B0,3.162277660168379,0,3.162277660168379%5D

http://kevinmehall.net/p/equationexplorer/vectorfield.html#xi+yj%7C%5B-10,10,-10,10%5D

http://kevinmehall.net/p/equationexplorer/vectorfield.html#-10x/(x%5E2+y%5E2)i-10y/(x%5E2+y%5E2)j%7C%5B0,10,0,10%5D

http://www.falstad.com/vector3d/

The Gravitational Field

The gravitational field strength is defined as the force of gravity acting on a 1kg object at a point in space.

The units on gravitational field strength are N/kg.

$$\vec{F}_g = \frac{G m_1 m_2}{r^2} \quad \text{let } m_1 = 1\text{kg}.$$

$$\boxed{\vec{g} = \frac{Gm}{r^2}}$$

m - mass creating the field.

G - $N \cdot m^2/kg^2$

units on g -> N/kg.

Newton - $kg\,m/s^2$

$N/kg \leftrightarrow m/s^2$

at surface of earth

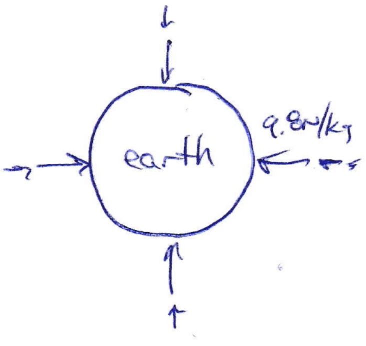
$$\vec{g} = \frac{G M_e}{r^2} = 9.8\,N/kg = 9.8\,m/s^2$$

Variables Required:

- Mass of earth, $M_e = 5.97 \times 10^{24}$kg
- Radius of Earth, $R_e = 6.38 \times 10^{6}$m
- $G = 6.67 \times 10^{-11}\ N \cdot m^2/kg^2$

*

$$\vec{F}_g = m\vec{g}$$



2. Electric Forces and Fields

Electric Force

1. Fe varies directly with the magnitude of the charge.

$$F_e \propto q$$

$q \rightarrow$ charge (measured in Coulombs - C)

2. Fe varies indirectly (inversely) with the square of the distance between the charges.

$$F_e \propto \frac{1}{r^2}$$

$$F_e \propto \frac{q_1 \cdot q_2}{r^2}$$

$$\downarrow$$

$$\boxed{F_e = \frac{k q_1 \cdot q_2}{r^2}}$$

k - Coulomb's Constant $= 9.0 \times 10^9 \, N \cdot m^2/C^2$

Example:

Compare the Electric Forces to the Gravitational Forces between an electron and a proton that are 1.0×10^{-10}m apart.

$\oplus \longleftarrow 1\times10^{-10}\,m \longrightarrow \ominus$

$m_e = 9.11\times10^{-31}$kg

$q_e = -1.602\times10^{-19}$C

$m_p = 1.67\times10^{-27}$ kg

$q_p = +1.602\times10^{-19}$C

$$F_g = \frac{G m_e m_p}{r^2} = 1.0\times10^{-47} N.$$

$G = 6.67\times10^{-11}\, N\cdot m^2/kg^2$

$$F_e = \frac{k q_e q_p}{r^2} = 2.3\times10^{-8} N$$

$k = 9.0\times10^{9}\, N\cdot m^2/C^2$

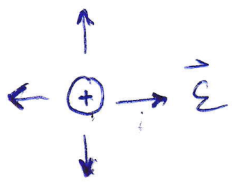
$\sim 2.3\times10^{39}$ x's stronger

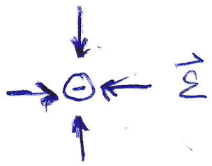
Electric Fields

The electric field strength is defined as the magnitude of the electric force acting on a 1C charge at a point in space.

The units on electric field are N/C.

By definition the direction the electric field points is the direction a positive charge would move.





$F_e = \frac{k q_1 q_2}{r^2}$ let $q_1 = 1C$

$\vec{\varepsilon}$ electric field strength

$$\boxed{\vec{\varepsilon} = \frac{kq}{r^2}}$$

$q \rightarrow$ charge creating the field.

units on $\vec{\varepsilon} = N/C$

$k \rightarrow N \cdot m^2/C^2$

$$\boxed{\vec{F}_e = q\vec{\varepsilon}}$$

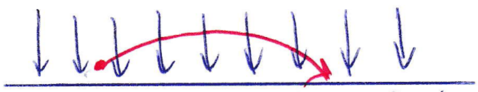
force on a particle in a field.

Uniform Fields

Gravitational

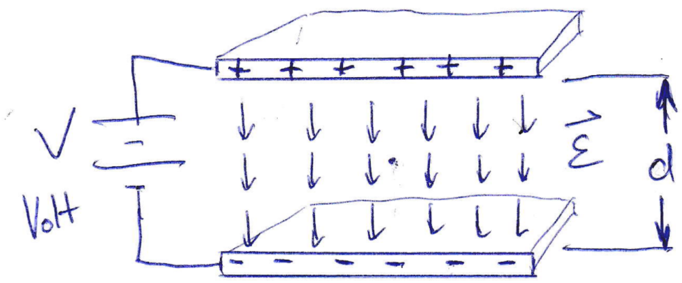
$g = 9.8\ N/kg\ [\downarrow]$

uniform in magnitude & direction.



assume earth is flat

Electric



$$\vec{\varepsilon} = \frac{V}{d} \quad \frac{(\text{volts})}{(\text{metre})}$$

↓

N/C

Volt → J/C

$$\frac{V}{m} \Longleftrightarrow \frac{N}{C}$$

Sample Problems

1. Electric field created by two particles

2. Acceleration of a charged particle in a uniform field

Sample problem #1

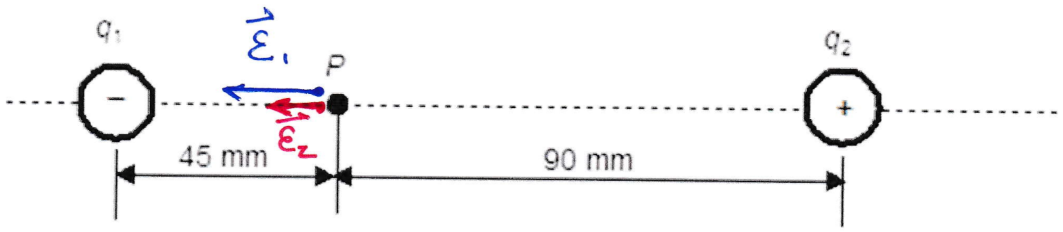
*

Two charged spheres charges are 135 mm apart. The charge on q_1 is -5.6×10^{-7}C and the charge on q_2 is 11.2×10^{-7}C.

a. Find the net electric field at point P.

b. What would the force on an electron be if it was placed at point P? (the charge on electron is -1.602×10^{-19}C)

$k = 9.0\times10^{9}\ N\cdot m^2/C^2$



a. $\vec{\varepsilon}_{TOT} = \vec{\varepsilon}_1 + \vec{\varepsilon}_2$

$\vec{\varepsilon}_1 = \frac{kq_1}{r^2} = 2.5\times10^{6}\ N/C\ [\leftarrow]$

$\vec{\varepsilon}_2 = \frac{kq_2}{r^2} = 1.2\times10^{6}\ N/C\ [\leftarrow]$

$\vec{\varepsilon}_{TOT} = 3.7\times10^{6}\ N/C\ [\leftarrow]$

Tend to lose electrons	(+)
	human hands (dry)
	glass
	human hair
	nylon
	cat fur
	silk
	cotton
	steel
	wood
	amber
	ebonite
	plastic wrap
Tend to gain electrons	Teflon®
	(–)

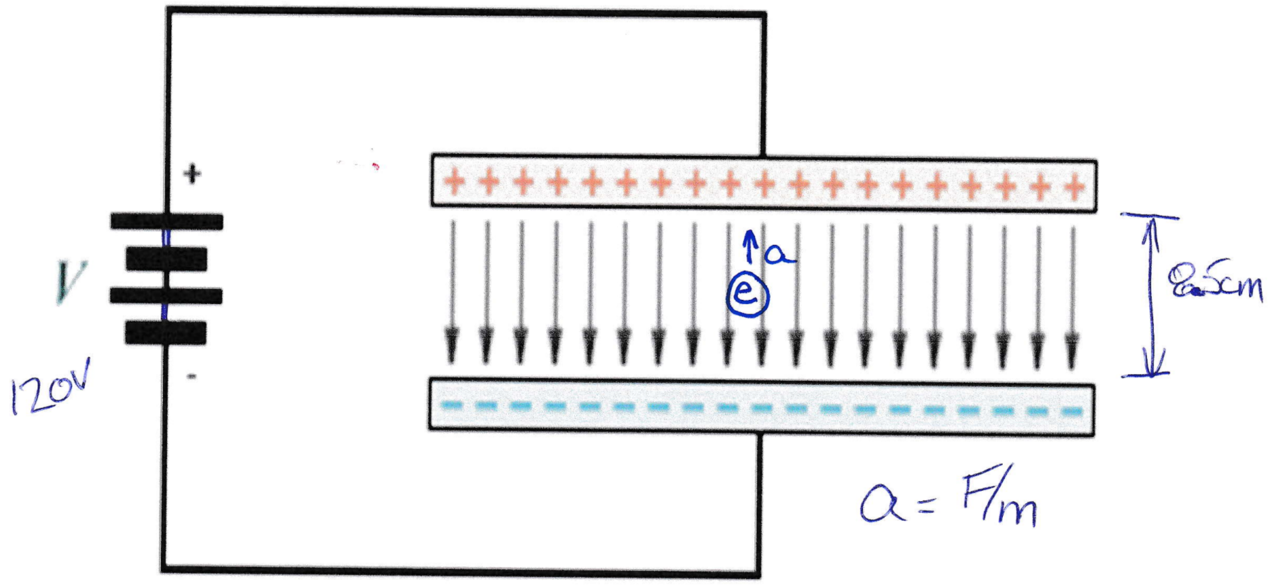
b. $\vec{F} = q\vec{\varepsilon}$

$= (1.602\times10^{-19}C)(3.7\times10^{6}N/C)$

$= 6.0\times10^{-13}\ N\ [\rightarrow]$

Sample problem #2

An electron is place in the middle of a two charged plates which are separated by 8.5 cm. If the voltage across the plates is 120V what is the acceleration of the electron? (the charge on an electron is -1.602×10^{-19}C and the mass of an electron is 9.11×10^{-31}kg)



$$a = F/m$$

$$\vec{\varepsilon} = \frac{V}{d} = \frac{120V}{0.085m} = 1412\ V/m\ [\downarrow] = 1412\ N/C\ [\downarrow]$$

$$\vec{F} = q\vec{\varepsilon} = (1.602\times10^{-19}C)(1412\ N/C) = 2.262\times10^{-16}\ N\ [\uparrow]$$

$$\vec{a} = \vec{F}/m = \frac{2.262\times10^{-16}\ N\ [\uparrow]}{9.11\times10^{-31}\ kg} = 2.5\times10^{14}\ m/s^2\ [\uparrow]$$

Comparison : Gravitational vs. Electric Field Formulas

Force

Gravity

$$\vec{F}_g = \frac{Gm_1m_2}{r^2}$$

Electric

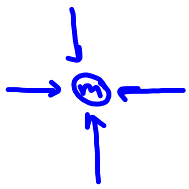
$$\vec{F}_e = \frac{kq_1q_2}{r^2}$$

Field Strength

$$\vec{g} = \frac{Gm}{r^2} \quad (N/kg) \quad (m/s^2)$$

$$\vec{F} = m\vec{g}$$

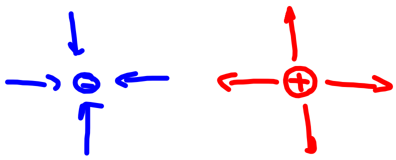
point mass



$$\vec{\mathcal{E}} = \frac{kq}{r^2} \quad (N/C)$$

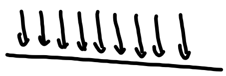
$$\vec{F}_e = q\vec{\mathcal{E}}$$

point charge

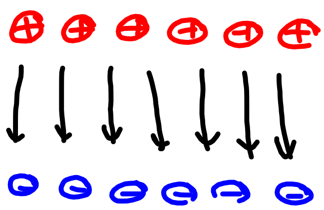


Uniform Fields

assume earth is flat



$g = 9.8\ N/kg$



uniform $\vec{\mathcal{E}}$

$$\vec{\mathcal{E}} = \frac{V}{d} \quad (V/m)$$

V/m equivalent to N/C.