Dynamics

Topics covered:

- Newton's Laws of Motion
- 2-D Forces
- Inclined Plane Problems
- Block and Pulley Problems
- Uniform Circular Motion
- Force Fields
- Gravitational Field Strength
- Electric Field Strength (Point Charges)
- Electric Field Strength (Parallel Plates)
- Universal Law of Gravitation, Coulomb's Law
- Magnetic Fields
- Magnetic Force
- Fields and Forces Equations (Summary)

Newton's Laws of Motion

Newton's First Law: Law of Inertia

An object will remain at rest or in uniform motion unless acted upon by an external, unbalanced force

Newton's Second Law

$\vec{F}_{NET} = m\vec{a}$ Where the net force ($\vec{F}_{NET}$) is the sum of all the force acting on an object

Newton's Third Law: Action-Reaction

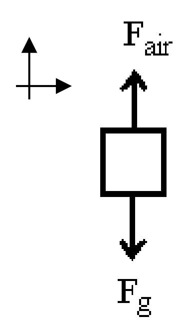
For every action (applied) force, there exists a reaction force that is equal in magnitude and opposite in direction to the action force.

N.B. Action / reaction forces act on ***different objects***.

Free Body Diagrams (FBD's)

- Draw a circle/box to represent the object.
- Draw and label forces as vectors (arrows) originating from the centre of the box/circle, pointing away.
- The relative lengths of the vectors must match the relative magnitudes of the forces
- The direction of the vectors must match the direction of the forces
- Indicate which directions are to be considered positive

e.g.



Macroscopic Electromagnetic (i.e. Common) Forces

Type of Force	Symbol	Description	Useful Info	Example
Applied Force	$\vec{F}_{app}$	Any general contact force	• Its symbol can depend on the object providing the force (i.e. $\vec{F}_{engine}$, $\vec{F}_{girl}$, $\vec{F}_{finger}$ etc.)	A human pushing a refrigerator
Normal	$\vec{F}_N$	Forces applied by surfaces	• The direction of this force is always perpendicular to the surface	A refrigerator on the floor
Tension	$\vec{F}_T$	Forces applied by ropes, strings, cords, etc	• Only *pull*s ("Can't push a rope")	Pulling a refrigerator with a rope
Gravity	$\vec{F}_g$	Gravitational attraction of any object to the *Earth only*	• $\vec{F}_g = m\vec{g}$ * this equation is only valid 'near' the surface of the earth ($\vec{g} = 9.8\ m/s^2$ [↓]) • An attractive force only • *Weight =* the force of gravity on an object, measured in Newtons, *N* (not *mass*, measured in *kg*)	The earth pulls downwards on a hat dropped from a bridge towards the water below
Friction	$\vec{F}_f$	Any force that opposes motion	• $\lvert\vec{F}_f\rvert = \mu\lvert\vec{F}_N\rvert$ *The direction of this force is always opposite the direction of motion • Friction caused by air is usually written as $\vec{F}_{air}$	
Static Friction	$\vec{F}_S$	forces that prevent stationary objects from moving	• $\vec{F}_S > \vec{F}_K$ • When applying a force on a stationary object, the frictional force is static, and as soon as the object starts to move, the friction immediately changes to kinetic	the floor preventing the movement of a large refrigerator when an applied force is used
Kinetic friction	$\vec{F}_K$	forces that oppose the motion of moving objects		the floor resisting the motion of a refrigerator as it moves

Solving 2-D Forces Problems – Component Method

- Separate forces into those that exist in the 'y' direction and those that exist in the 'x' direction.
- Add the forces (remember they are vectors!) the find the net force in each the 'y' and 'x' directions, using the following format:

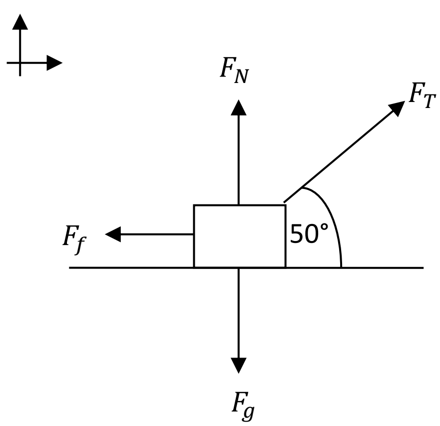
$$\sum \vec{F}_x = \vec{F}_{1x} + \vec{F}_{2x} + \vec{F}_{3x} + \ \ldots$$
$$\sum \vec{F}_y = \vec{F}_{1y} + \vec{F}_{2y} + \vec{F}_{3y} + \ \ldots$$

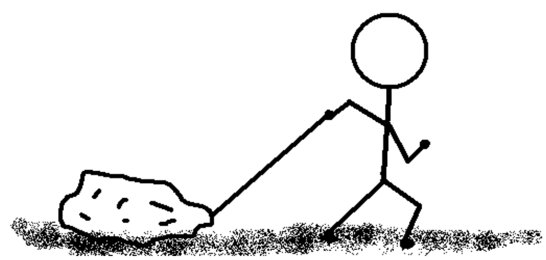
- Apply these net forces to Newton's second law:

$$\sum \vec{F}_x = \vec{F}_{1x} + \vec{F}_{2x} + \vec{F}_{3x} + \ \ldots = m\vec{a}_x$$
$$\sum \vec{F}_y = \vec{F}_{1y} + \vec{F}_{2y} + \vec{F}_{3y} + \ \ldots = m\vec{a}_y$$

e.g. A person pulls a 45 kg sack of potatoes along the ground using at rope, at an angle of 50° up from the horizontal. If the coefficient of friction between the sack and the ground is 0.29 and the person is pulling with a magnitude of 210 N, determine the horizontal acceleration of the sack.

FBD:





$$\sum \vec{F}_x = \vec{F}_f + \vec{F}_T \cos 50° = m\vec{a}_x$$
$$\sum \vec{F}_y = \vec{F}_N + \vec{F}_g + \vec{F}_T \sin 50° = m\vec{a}_y$$

From the *y*-direction:

$$\vec{F}_N + \vec{F}_g + \vec{F}_T \sin 50° = 0 \qquad \text{(since } \vec{a}_y = 0\, m/s^2\text{)}$$
$$\vec{F}_N = -\vec{F}_g - \vec{F}_T \sin 50°$$
$$\vec{F}_N = -[-(45\, kg)(9.8\, m/s^2[\uparrow])] - (210\, N) \sin 50°$$
$$\vec{F}_N = -[-(45\, kg)(9.8\, m/s^2[\uparrow])] - (210\, N) \sin 50°$$
$$\vec{F}_N = 280.1\, N[\uparrow]$$

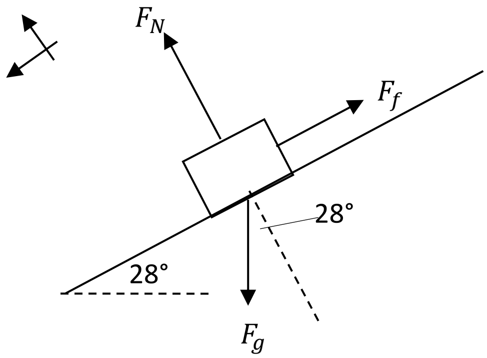
From the *x*-direction:

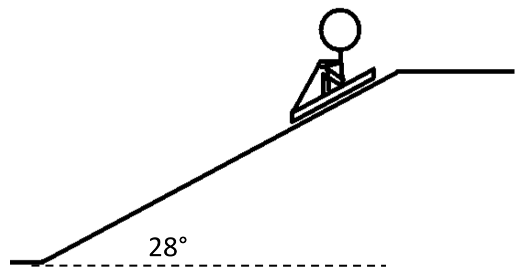
$$m\vec{a}_x = \vec{F}_f + \vec{F}_T \cos 50°$$
$$\vec{a}_x = \frac{\mu|\vec{F}_N| + \vec{F}_T \cos 50°}{m}$$
$$\vec{a}_x = \frac{-(0.29)|280.1\, N| + (210\, N) \cos 50°}{45\, kg}$$
$$\vec{a}_x = 1.2\, m/s^2\ [\rightarrow]$$

The Inclined Plane

Analysis of the inclined plane involves rotating your coordinate system. Instead of considering motion in the *x* and *y* directions, consider the motion the directions *parallel* ($\vec{F}_{\parallel}$) and *perpendicular* ($\vec{F}_{\perp}$) to the surface of the incline.

e.g. Find the acceleration of a person sliding down a snowy hill (as pictured) if the coefficient of friction between the sled and the snow is 0.33.





$$\sum \vec{F}_{\perp} = \vec{F}_N + \vec{F}_g \cos 28° = m\vec{a}_{\perp} = 0$$
$$\sum \vec{F}_{\parallel} = \vec{F}_g \sin 28° + \vec{F}_f = m\vec{a}_{\parallel}$$

From the *perpendicular*-direction:

$$\vec{F}_N = -\vec{F}_g \cos 28°$$

From the *parallel*-direction:

$$ma_{\parallel} = F_g \sin 28° - \mu\left|\vec{F}_N\right|$$
$$ma_{\parallel} = mg \sin 28° - \mu mg \cos 28°$$
$$a_{\parallel} = g(\sin 28° - \mu \cos 28°)$$
$$a_{\parallel} = 1.7\ m/s^2\ [down\ the\ hill]$$

String and Pulley Problems

Assumptions:

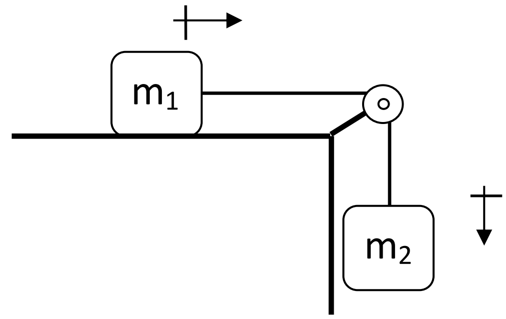
- The strings are infinitely strong (will never break)
- The properties of the strings are constant (suffer no wear under stress)
- All pulleys are frictionless

The force applied by one end of a string is equal in magnitude to the force applied by the other end of the string (though their directions, in general, are not equal).

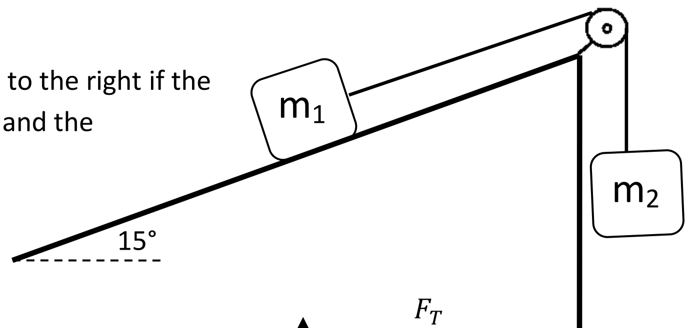
Objects connected by strings form a *system*. All parts of a system have the same magnitude of acceleration, though the directions of each part are, in general, not equal.

Strategy when solving string and pulley problems:

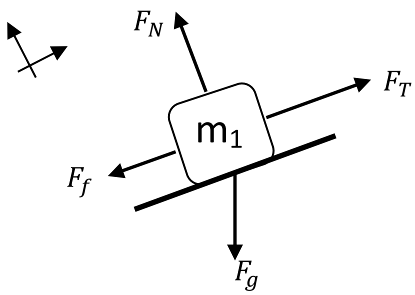
- Draw an FBD for each object
- Determine the direction of motion (if any) for each object, and make it the positive direction for that object
- Sum your forces for each object as you would for any 2-D dynamics problem, then isolate for your unknown and solve.

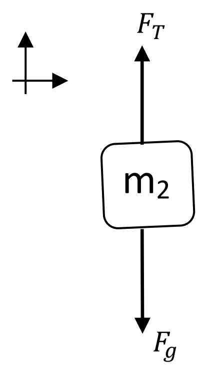


e.g. Determine the acceleration of the system to the right if the coefficient of kinetic friction between m_2 and the incline is 0.14 ($2m_1 = m_2$).



FBD's:





$$\sum \vec{F}_{\parallel} = \vec{F}_T + \vec{F}_f + \vec{F}_g \sin 15° = m_1 \vec{a}_{\parallel}$$
$$\sum \vec{F}_{\perp} = \vec{F}_N + \vec{F}_g \cos 15° = m_1 \vec{a}_{\perp} = 0$$

$$\sum \vec{F}_y = \vec{F}_T + \vec{F}_g = m_2 \vec{a}_y$$

From the *perpendicular*-direction:

$$\vec{F}_N = -\vec{F}_g \cos 15°$$
$$\left|\vec{F}_N\right| = \left|\vec{F}_g \cos 15°\right| \qquad \textit{(1)}$$

From the *y*-direction:

$$\vec{F}_T = m_2 \vec{a}_y - \vec{F}_g$$
$$-F_T = m_2 a_y - F_g$$
$$F_T = F_g - m_2 a_y \qquad \textit{(2)}$$

From the *parallel*-direction:

$$\vec{F}_T = m_1 \vec{a}_{\parallel} - \mu\left|\vec{F}_N\right| - \vec{F}_g \sin 15°$$
$$F_T = m_1 a_{\parallel} - \left(-\mu(F_N)\right) - \left(-F_g \sin 15°\right)$$

And substituting *(1)* and *(2)* (since tension is the same), and employing $\vec{F}_g = m\vec{g}$,

$$m_2 g - m_2 a_y = m_1 a_{\parallel} + \mu(m_1 g \cos 15°) + m_1 g \sin 15°$$

But $2m_1 = m_2$ and $a_{\parallel} = a_y$ since the blocks form a system,

$$2m_1g - 2m_1a_{\parallel} = m_1a_{\parallel} + \mu(m_1\text{g}\ \cos 15°) + \ m_1\text{g}\ \sin 15°$$

Cancelling the masses and solving for *a*

$$-3a = \mu\text{g}\ \cos 15° + \ \text{g}\ \sin 15° - \ 2g$$

$$a = \frac{-g(\mu \cos 15° + \sin 15° - 2)}{3}$$

$$a = \frac{-(9.8\ \text{m/s}^2)\ [(0.14)\cos 15° + \ \sin 15° - 2\ ]}{3}$$

$$a = 5.2\ \text{m/s}^2$$

<u>Uniform Circular Motion</u>

Uniform Circular Motion – motion of an object moving in a complete (or part of) circle with a constant speed

Centripetal ("centre-seeking") force

The centripetal is actually a label given to one or more *real* forces responsible for maintaining an object in uniform circular motion. It describes the *role* of the force(s). Consider the following analogy:

- A baseball player is a human who plays baseball
- The centripetal force is a force that keeps on object moving in a circle at a constant speed

⇨ Humans actually exist, but a baseball player doesn't – it's an action a human does. Similarly, the centripetal force doesn't actually exists, it describes what some other real (or combination of other real) forces do.

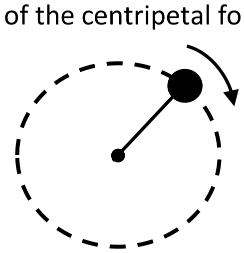
Properly defined:

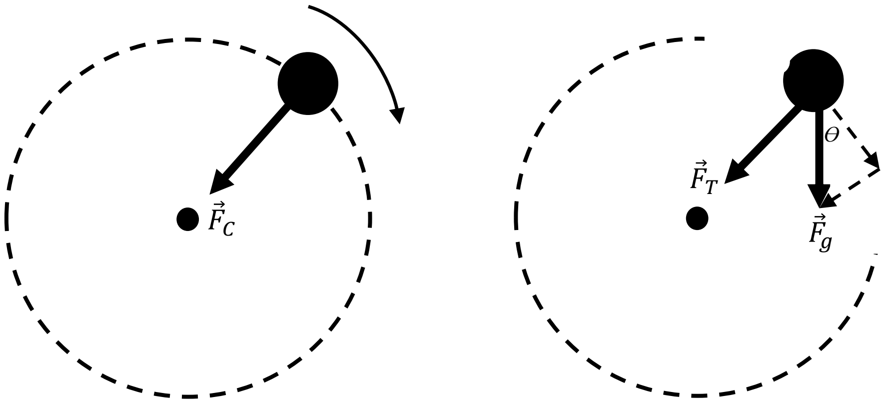
Centripetal Force ($\vec{F}_c$) – the vector sum of all the forces acting on the object *towards the centre of Motion*

How to find the Centripetal force:

Centripetal means centre-seeking. So any force (or component of a force) that is directed towards the centre of motion is part of the centripetal force.

e.g. a mass spun with a rope in a vertical circle





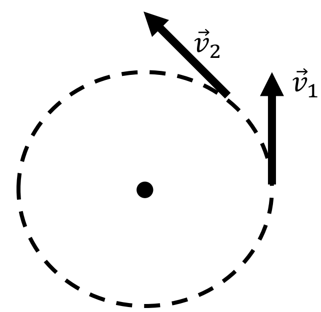
$$\sum \vec{F}_{towards\ centre\ of\ motion} = \vec{F}_c = \vec{F}_T + \vec{F}_g \sin\theta$$

The most common forces that make up the centripetal force are:

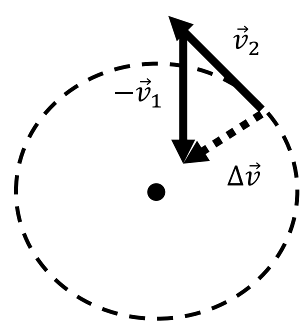
$\vec{F}_T$	tension	(from a rope, an arm, etc)
$\vec{F}_N$	normal force	(bottom of a bucket/test tube, the sides of a drum, etc)
$\vec{F}_f$	frictional force	(the surface of a record, a merry-go-round, etc)
$\vec{F}_g$	gravitational force	(gravitational pull of the earth near the surface, or orbits around a massive objects like planets, stars, etc such that $\vec{F}_g = \frac{Gm_1m_2}{r^2}$ must be used)

Centripetal Acceleration

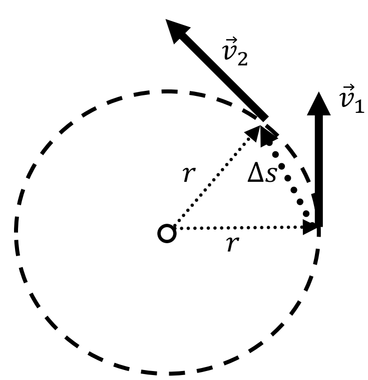
If an object is undergoing uniform circular motion (in this case anti-clockwise), its speed is constant ($|\vec{v}_2| = |\vec{v}_1|$) as its direction continuously changes, as shown to the right.



Using the velocity vectors, the change in velocity, $\Delta\vec{v}$, can be determined by creating the following triangle:

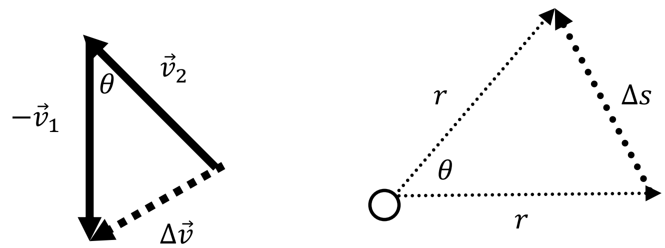


A second can be created triangle using the radii from the centre of motion to each velocity vector and their difference, Δs



Both are isosceles triangles that share a common angle, ϑ, and so are similar triangles, such that:

$$\frac{\Delta v}{v} = \frac{\Delta s}{r} \qquad \text{where } v = |\vec{v}_2| = |\vec{v}_1|$$



Dividing both sides by the time interval, Δt, between the instants of the two velocity vectors gives

$$\frac{\Delta v}{v\Delta t} = \frac{\Delta s}{r\Delta t}$$

and

$$|\vec{a}| = \frac{\Delta v}{\Delta t} = \frac{v\Delta s}{r\Delta t}$$

For very small angles ($\theta \to 0$), Δs approaches the arc length, s, of the object's circular path. This arc length is also the distance the object travelled during the time interval, Δt

$$\frac{\Delta s}{\Delta t} = \frac{s}{\Delta t} = \frac{d}{\Delta t} = v$$

So

$$|\vec{a}| = \frac{v\Delta s}{r\Delta t} = \frac{v(v)}{r}$$

Centripetal acceleration, a_c , of an object undergoing uniform circular motion is as follows:

$$a_c = \frac{v^2}{r}$$

Direction of Centripetal Acceleration

Since $\vec{v}_2$ and $\vec{v}_1$ are of equal magnitude, the difference, $\Delta\vec{v}$ will always point directly to the centre of motion, and hence, centripetal acceleration is always point towards the centre of motion.

Alternate Forms – Centripetal Acceleration

To calculate the centripetal acceleration of an object, its speed must be known. If it is not known, it can be calculated from its period and the radius of the circle it traces out (both measureable quantities):

$$v = \frac{2\pi r}{T}$$

Centripetal acceleration can now also be expressed as:

$$a_c = \frac{\left(2\pi r/_T\right)^2}{r} = \frac{4\pi^2 r^2}{rT^2} = \frac{4\pi^2 r}{T^2}$$

Using frequency instead of period:

$$a_c = \frac{4\pi^2 r}{T^2} = 4\pi^2 r f^2$$

Centripetal Force

According to Newton's second law, $\vec{F}_{NET} = m\vec{a}$, and if $a = \frac{v^2}{r}$, then the centripetal force, F_c, is

$$F_c = \frac{mv^2}{r}$$

Or in terms of radius of motion and period or frequency:

$$F_c = \frac{mv^2}{r} = \frac{4\pi^2 mr}{T^2} = 4\pi^2 mrf^2$$

Strategy when solving uniform circular motion problems

1. Draw a FBD for the object in motion
2. Determine the location of centre of motion
3. Sum all the forces along this direction (along the line from the object to the centre of motion) and solve

Notes:

- F_c is always constant ($F_c = \frac{mv^2}{r} = \frac{4\pi^2 mr}{T^2} = 4\pi^2 mrf^2 = CONSTANT$ - If the F_c changes, then the circular motion is no longer uniform, and this treatment no longer applies
- If the radius of motion is fixed, F_c is proportional to v^2 (increasing F_c increases the speed at which the object rotates)
- If F_c is increased and the speed at which the object rotates is desired to be remained fixed, then the radius of motion must be decreased, since F_c is proportional to $\frac{1}{r}$

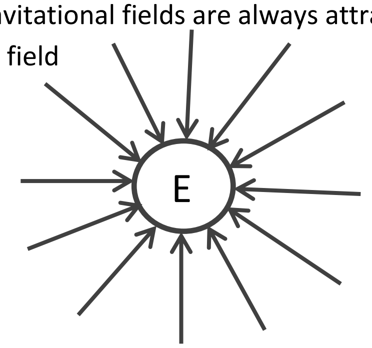
Force Fields

Force Field - 3-dimensional space in which a force is applied

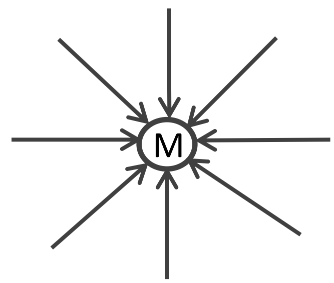
Force Fields are drawn using field lines. The strength of the field at any point in the field is indicated by the concentration of field lines near that point. Field lines never cross each other.

Gravitational Fields:

- Gravitational fields are always attractive, and so arrows are drawn towards the mass creating the field



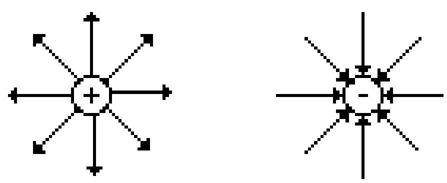
Gravitational field of earth



Gravitational field of the moon

Electric Fields (point charges):

- By convention, a positive 'test charge' is always used, such that a positive charge will be attracted to a negative source charge and repelled by a positive one
- As a result, arrows are drawn towards a negative source charge and away from a positive source charge



Inverse Square law

Imagine waking up blindfolded and ear-plugged in the middle of a field. There is a large pot of soup cooking somewhere nearby. Would be able to locate it?

Of course! You could use your sense of smell: the stronger the smell, the closer you are. Our sense of smell relies on detecting soup particles in the air as they leave the pot and enter the surrounding air. Spreading out evenly (if there is no wind!) in three dimensions, the soup-particle density (number of particles per volume) decreases the further away from the pot you are, so the smell is less strong.

This is due to the **Inverse Square Law**, a purely geometrical phenomenon that describes what happens when you start expanding the surface area of spheres:

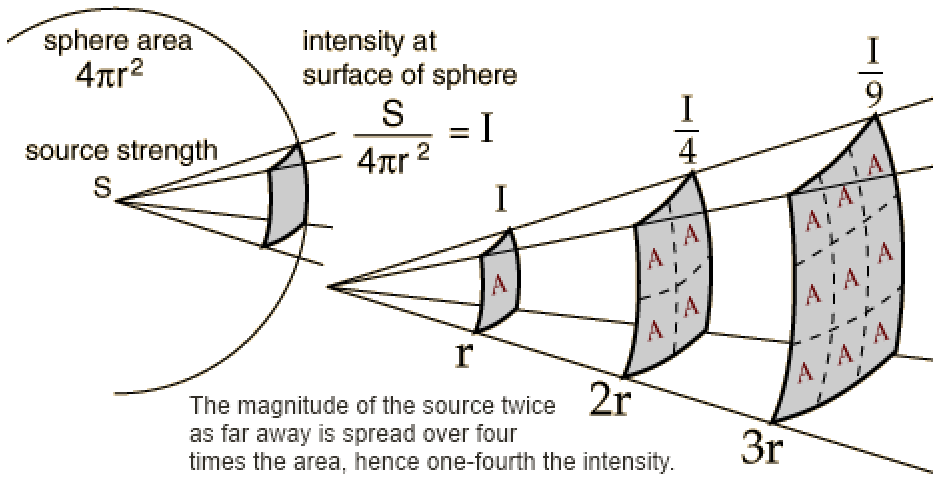


Image courtesy of *Hyperphysics*, Georgia State University

The inverse square law, along with many other physical phenomena (like smell!), describe the how the strength of gravitational and electric fields change the further you move away from them

Gravitational Field Strength

The strength of a gravitational field depends on the amount of mass of the object producing the field, and the distance away from it (objects are often assumed to be point particles).

Gravitational Field Strength ($\vec{g}$) $\vec{g} = \frac{Gm}{r^2}$ *[towards mass]* units = *N/kg* (or *m/s^2*)

G =gravitational constant = $6.67x10^{-11}$ $N{\cdot}m^2/kg^2$
m = mass of object creating the field
r = distance from some location to object

Gravitational Field Strength describes the amount of force, for every kilogram of mass, that some object (*not* the one creating the field!) will experience at one particular location in space (hence the units, *N/kg*).

Simplified further, the units are the same as for acceleration, m/s^2, as the gravitational field strength all describes how an object will accelerate at one particular location in space.

Gravitational Field Strength at the *Surface* of the *Earth*

$$\vec{g} = \frac{Gm_{Earth}}{r_{Earth}^2} = \frac{(6.67\times10^{-11}\ N{\cdot}m^2/kg^2)(5.98\times10^{24}kg)}{(6.37\times10^6 m)^2} = 9.8\ m/s^2 \ \ !!!$$

Electric Field Strength – Point Charges

The strength of an electric field depends on the amount of charge the object producing the field has, and the distance away from it (objects are often assumed to be point particles).

Electric Field Strength ($\vec{\varepsilon}$) $\varepsilon = \frac{kq}{r^2}$ *[towards or away from charge]* units = *N/C*

k = electrostatic (coulomb) constant = $8.99 \times 10^9\ N{\cdot}m^2/C^2$
q = charge of object creating the field (can be – or +)
r = distance from some location to object

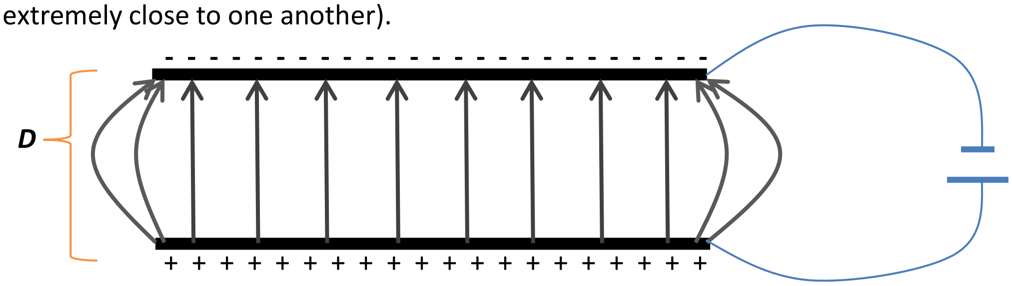
Electric Field Strength describes the amount of force, for every coulomb of charge, that some object (*not* the one creating the field!) will experience at one particular location in space (hence the units, *N/C*).

Electric Field Strength – Parallel Plates

Not all force fields, however, follow the inverse square law (only fields from point objects will). A *parallel plate apparatus*, which consists of two, oppositely charged, metallic plates will create a ***uniform*** field in the space between its plates.

As a positive test charge moves closer to the negative plate, it is attracted more strongly, but at the same time repelled less strongly from the positive plate, and the net result is a constant field toward the negative plate. The (horizontal component of) attraction from a location on the negative plate to the left of the test charge is cancelled by the attraction from an equidistant location on the right of the test charge. As long as the test charge is sufficiently far from the edges, all horizontal attractions (and repulsions) are cancelled.

Outside the plates, no electric field exists as the oppositely charged plates cancel each other out (plates tend to be kept extremely close to one another).



Electric Field Strength ($\vec{\varepsilon}$) $\varepsilon = \frac{\Delta V}{D}$ *[towards negative or positive plate]* units = *N/C*

ΔV = potential difference across the plates
D = plate separation

Universal Law of Gravitation, Coulomb's Law

Newton's Law of Universal Gravitation:
The gravitational force of attraction experienced by an object depends on the magnitude of its mass and the strength of the gravitational field it is located in:

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

According to Newton's 3rd Law, when one object attracts another, it is also being attracted *by* the other. A mutual attraction exists between any (every) two objects in the universe, such that both objects experience a force equal in magnitude but opposite in direction:

$$F_g = m_2\left(\frac{Gm_1}{r^2}\right)$$

$$F_g = \frac{Gm_1m_2}{r^2}$$

Coulomb's Law:
The attractive or repulsive electric force experienced by an object depends on the magnitude of its charge and the strength of the electric field it is located in:

$$\vec{F_E} = q\vec{\varepsilon}$$

The direction of the electric force (i.e. attraction or repulsion) depends on whether the two charges are the same (repulsion) or opposite (attraction). According to Newton's 3rd Law, when one object attracts/repels another, it is also being attracted/repelled *by* the other. A mutual attraction/repulsion exists between any (every) two charged objects in the universe, such that both objects experience a force equal in magnitude but opposite in direction:

$$F_E = q_2\left(\frac{kq_1}{r^2}\right)$$

$$F_E = \frac{kq_1q_2}{r^2}$$

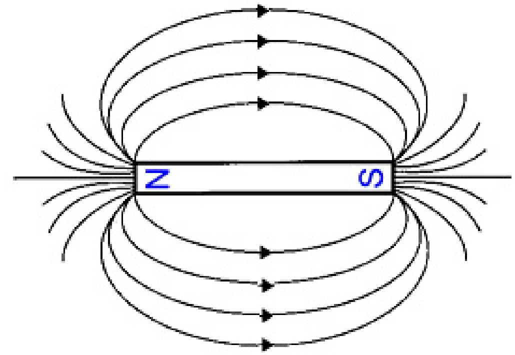
Force Constants
The gravitational constant, G, is very small. Relatively small objects are likely to have insignificant gravitational interactions.

The electrostatic constant (coulomb constant), k, is very large. Weakly charged objects will still have significant electrostatic interactions.

Magnetic Fields

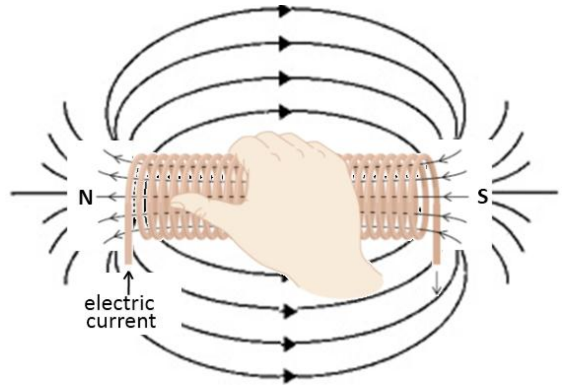
Bar Magnets

- By convention, the direction of the lines are from North to South (compasses point with North)
- Magnetic field lines are continuous (connected through the inside of the magnet)



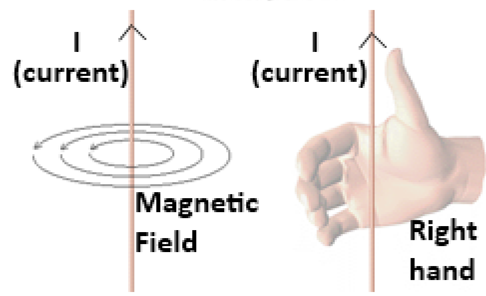
Solenoids

- A solenoid is a coiled conductor, and when electricity is passed through it, it produces a magnetic field outside itself identical to a bar magnet
- Inside the solenoid, the magnetic field is constant and points from South to North



Current-Carrying Conductors (Linear)

- When current passes through a conductor, a magnetic field is produced that encircles the conductor itself.

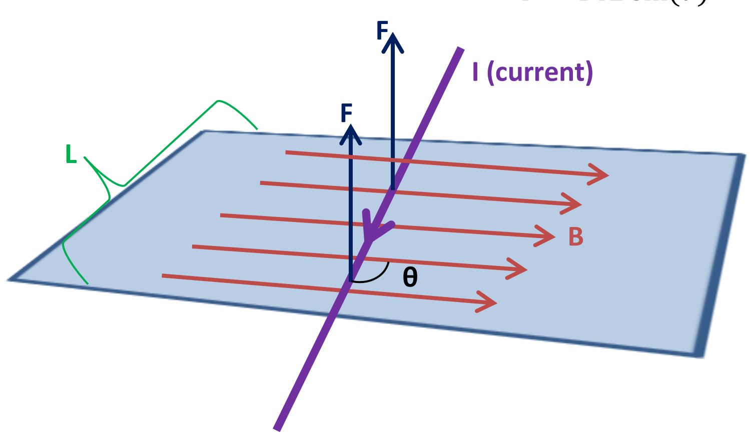


Magnetic Force

Magnetic Force on Current-Carrying Wires

For a length of wire, *L*, that experiences a uniform, external magnetic field, *B*, through which passes a current, *I,* a force, *F*, is created on the wire by the field according to the following expression:

$$F = BIL\sin(\theta)$$



F – force
B – magnetic field
L – length of conductor
I – current through the conductor
θ – angle between current magnetic field

Magnetic Force on Moving Charges

Current is defined as the number of particles (*n*), each with charge (*q*), moving past a point in a given time interval (*Δt*):

$$I = \frac{nq}{\Delta t}$$

Substituting into the equation above:

$$F = BIL\sin(\theta)$$

$$F = B\left(\frac{nq}{\Delta t}\right)L\sin(\theta)$$

But *L* is just the distance travelled by the charges in a given amount of time, so

$$L = d = v\Delta t$$

Substituting:

$$F = B\left(\frac{nq}{\Delta t}\right)(v\Delta t)\sin(\theta)$$

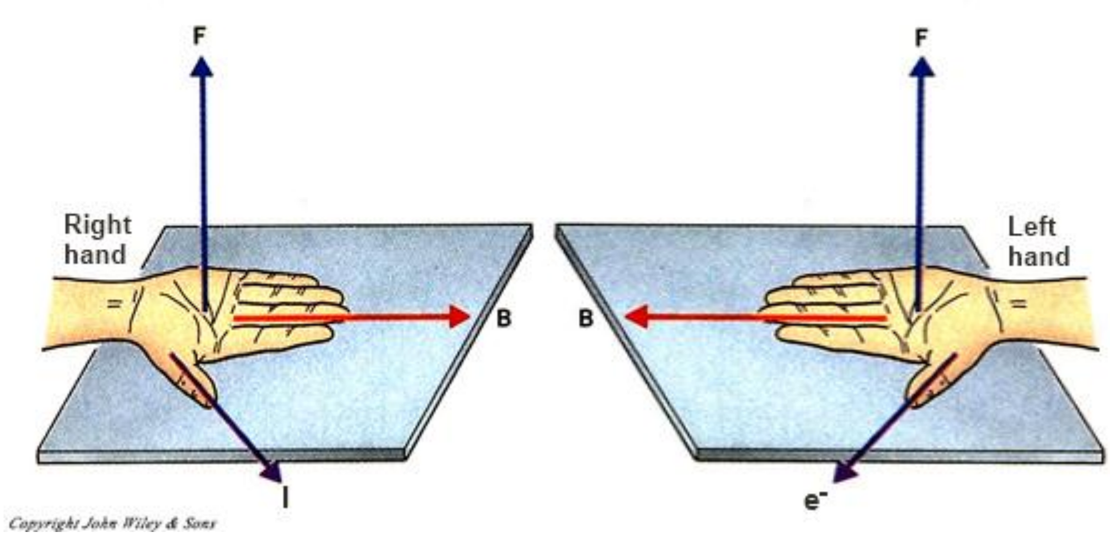
So, for a single charge (*n=1)*

$$F = qvB\sin(\theta)$$

q = charge of particle
v = velocity of particle
B = external magnetic field
ϑ = angle between the velocity ***v*** and the magnetic field ***B***

Direction of Magnetic Force

Magnetic Forces obey the right hand for conventional current and positively-charged particles, and the left hand rule for electron flow and negatively-charged particles, as shown below:



Centripetal Magnetic Force

According to RHR#3, magnetic force is always at right angles to a particle's motion -> Centripetal force! This causes the motion of charged particles moving through an external magnetic field to be circular!

$$F_{magnetic} = F_{centripetal}$$
$$qvB = \frac{mv^2}{r}$$
$$r = \frac{mv}{Bq}$$

The Mass Spectrometer

Following from the equation above, a charged particle could be accelerated to a predetermined speed and send it through a predetermined external magnetic field. By measuring the radius of the particles' subsequent circular motion, its mass-to-charge ratio (or, inversely, charge –to-mass ratio) could be determined.

It turns out that every charged particle has a unique charge-to-mass ratio (e.g. proton charge to mass ratio = 9.578 833 58 x10^7 C/kg), thus making identifying unknown particles (and combinations of particles, like atoms) in a sample quite easy.

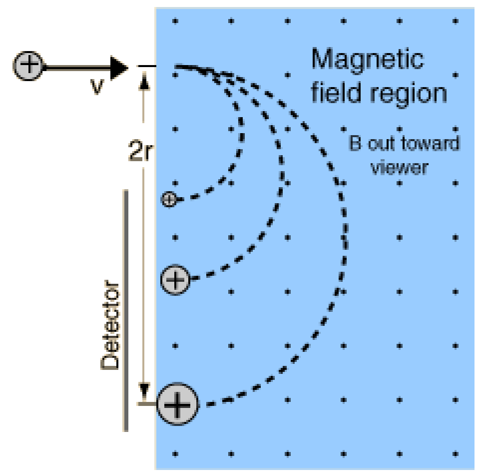


Image courtesy of Hyperphysics, Georgia State University

__**Fields and Forces Equations (Summary)**__

	Object Experiencing Force	Units	Field Strength	Units	Force	Units
Gravitation	(point) mass	kg	$g = \frac{Gm_1}{r^2}$	N/kg	$F_g = mg$ $F_g = \frac{Gm_1m_2}{r^2}$	N
Electric (Point Charges)	(point) charge	C	$\varepsilon = \frac{kq_1}{r^2}$	N/C	$F_e = q\varepsilon$ $F_e = \frac{kq_1q_2}{r^2}$	N
Electric (Parallel Plates)	(point) charge	C	$\varepsilon = \frac{\Delta V}{D}$	N/C	$F_e = q\varepsilon$ $F_e = q\frac{\Delta V}{D}$	N
Magnetic (Current-Carrying Conductors)	current-carrying conductor	A	-	-	$F = BIL\sin(\theta)$	N
Magnetic (Charged Particles)	(point) charge	C	-	-	$F = qvB\sin(\theta)$	N