**Physics 12**

**Booklet #4**

- Coulombs Law
- Electric Fields
- Electric Potential Energy
- Electric Potential
- Uniform Electric Fields
- Magnetic Fields
- Magnetic Fields surrounding wires
- Magnetic Force
- Motors
- Induction
- Transformers

Recall that electrons have a negative charge. If there are more electrons than protons in a substance it has a ____________________ charge. If there are more protons than electrons in a substance it has a _______________________ charge.

When an acetate ruler is rubbed on paper towel electrons move from the acetate strip to the paper towel, this give the ruler a ______________________ charge and the paper towel a _______________________ charge.

When vinyl is rubbed on fur, electrons move from the fur to the vinyl, this gives the vinyl a _____________________ charge and the fur a _________________________ charge.

| Two Positive Charges | Two Negative Charges | A Positive and a Negative |
|---|---|---|
| | | |

Law of Charges:

- 
- 
- 

Protons have a positive charge and electrons have a negative charge. Importantly the magnitude of these charges is ________________________. If a substance has 10 electrons and 5 protons it would have a charge of _________________________.

Since working with electrons and protons is very difficult we use a different unit for charge, the ___________________________,

1 coulomb = 6,241,509,629,152,650,000 elementary charges.

What is the force generated by electric charges?

$F_E$=

where k is Coulomb's constant:

$q_1, q_2$ are the

$r$ is the

Notice the similarity between this and

However, gravity always attracts but electric force can ________________ or _________________.

**Example:** Two objects are 4.0 metres apart, one has a charge of +2.0 C, while the other has a charge of -5.0 C. Will the two objects attract or repel each other and what is the electrostatic force between them?

Generally static charges we will experience are considerably less than a coulomb, typically the unit we will use will be the micro-coulomb ($\mu C$), this is a millionth of a coulomb.

$1\mu C =$

**Example:** Two objects 0.50 metres apart each have a charge of 2.0 $\mu C$. Will the objects attract each other or repel each other? What is the electrostatic force between them?

**Example:** A 55.6 $\mu$C object is near a -74.3 $\mu C$ object. Each object feels an attraction of 7.40 N towards each other. How far apart are they?

**Electric Fields**

Surrounding any charge there is an electric field. We define the direction the vectors point to be the direction a ___________________ charge would travel.

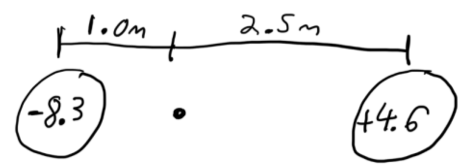
The strength of an electric field is determined by the ______________________ from the change and the _____________________ of the charge.

Another way to think of the field strength is as force per unit of charge

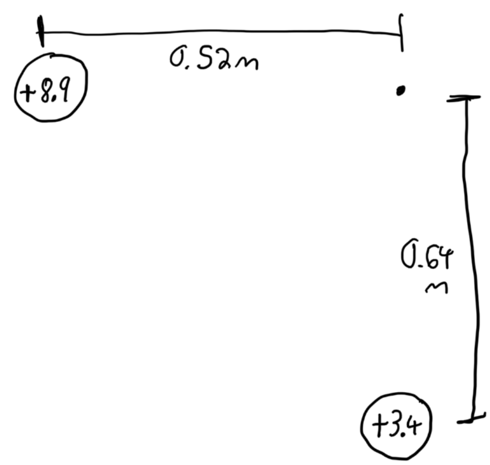
**Example:** What is the electric field strength at a point where a -2.00 $\mu C$ charge experiences an electric force of $6.30 \times 10^{-4}$ N?

**Example:** At a distance of 0.75m from a small charged object the electric field strength is $2.10 \times 10^{4}$ N/C. At what distance from this same object would the electric field strength be $4.50 \times 10^{4}$ N/C?

**Example**: What is the strength and direction of the electric field 1.0 metres right from a $-8.3\ \mu C$ charge and 2.5 metres left from a $+4.6\ \mu C$ charge as shown?




**Example:** What is the strength and direction of the electric field at a point if there is a $+3.4\ \mu C$ charge 0.64 metres to the South and a $+8.9\ \mu C$ charge 0.52 metres to the East.



**Electric Potential Energy**

Electric potential energy is analogous to ________________________ potential energy. It is the amount of energy a charged object has by virtue of being in an electric field, that energy can be converted into ________________________ energy if the object is left to accelerate.

Recall the formula for gravitational potential energy in a non uniform field was

The formula for electric potential energy in a non uniform field is

The zero point is when the two objects are ____________________ far apart.

**Example:** How much work must be done to bring a 4.0 uC charged object to within 1.0 m of a 6.0 uC charged object from a long way away?

In this case, bringing a positive charge near another positive charge requires ______________ therefore the work is ____________________.

**Example:** How much work must be done to bring a -7.0 $\mu$C charged object to within 0.50 m of a 5.0 $\mu$C charged object from a long way away?

In this case, bringing a negative charge near a positive charge _______________________ energy therefore work is _____________________.

**Example:** A 0.025 kg ball with a charge of 15.6 $\mu C$ is 0.062 metres from a 73.6 $\mu C$ charge. What will be the speed of the ball when it is 1.5 metres from the charge?

**Electric Potential**

To understand electric potential let us first consider gravitational potential.

Consider two balls each 5.0m above the ground, ball A has mass of 2.0 kg, ball B has mass of 5.0 kg.

Which ball has more potential energy?

Which ball have more potential energy per unit of mass?

Gravitational potential would be given by

or in a non-uniform field by

**Electric potential**

Electric potential is defined as electric potential energy per unit of charge

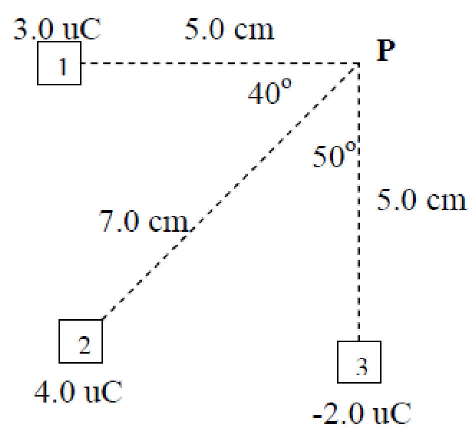
Electric potential is defined by the direction of a positive charge's motion so

positive charges move towards            potential

negative charges move towards            potential

The unit for electric potential is ______________________, electric potential is a ______________________.

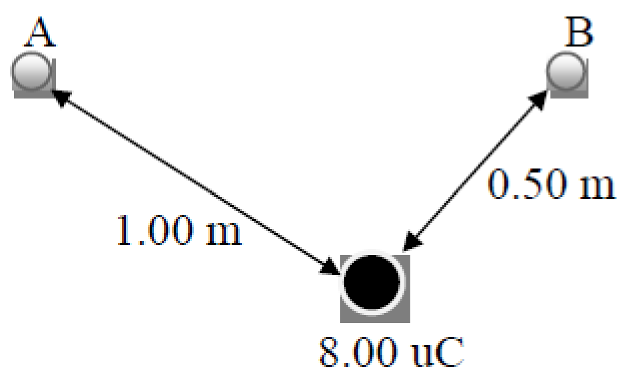
**Example 1:** Determine the electric potential at the point P.



**Potential Difference**

We often want to talk about the difference in electric potential between two points. Given two points (A and B) the electric potential difference between A and B is given by:

What is the electric potential difference between A and B?




What is the electric potential difference between B and A?

What is the work to move a 2.0 C change from A to B?

What is the work to move a 2.0 C change from B to A?

**Uniform Fields**

The electric field surrounding a point charge will vary considerably in strength and magnitude.

It is possible to set up a uniform electric field using charged plates.

The negative charge on the top plate causes the field to be pointed ____________________.

The positive charge on the bottom plate causes the field to be pointed ____________________.

Near the top plate the strength of the field is based mostly on the _______________________.

But as an object moves from the top to the bottom, the strength of the top plate's field decreases exactly by the same amount that the strength of the bottom plate's field increases.

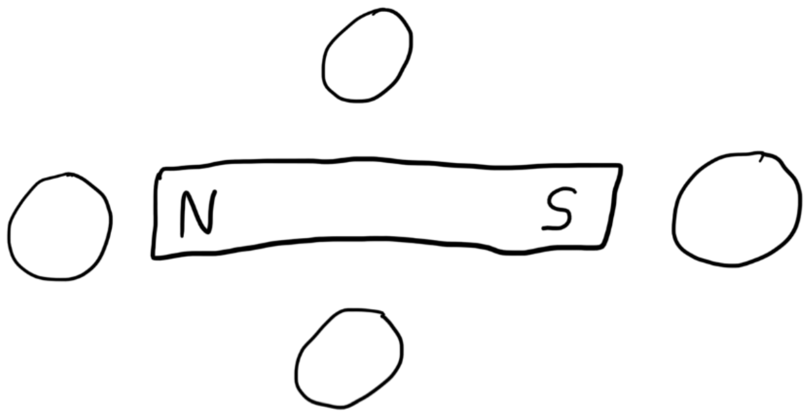
We need a new formula for this situation:

**Example:** Two plates are 0.15 metres apart. The top plate has an electric potential of 12 V and the bottom plate has an electric potential of $-4$ V. What is the strength and direction of the electric field between the plates?

**Example:** An electron with charge of $-1.6 \times 10^{-19}$C is accelerated from rest through a potential difference of 450 V. What is the kinetic energy gained by the electron?

**Magnetic Fields**

Magnets ______________ and _________________ other magnets without touching so there are magnetic fields surrounding magnets. We define the direction of a magnetic field surrounding a magnet to be the direction a compass would point if placed in that position, this is towards the _______________ pole and away from the _________________ pole.



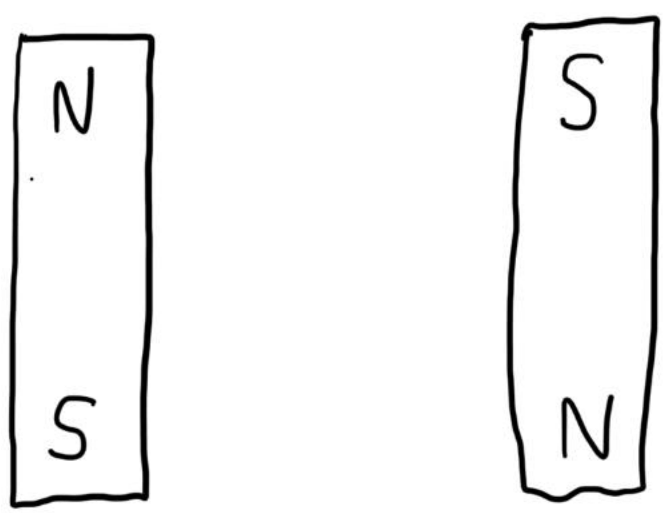

A compass is a useful navigation device on Earth because the Earth has a magnetic field, a compass points to the ____________ magnetic pole of the Earth which is fairly close to the geographic ________________ pole.

The major difference between magnetic fields and electric fields is that point charges in electric fields have charges which are either _________ or _____________. Magnets _________________ have _____________ a North and a South Pole.

One way to represent the magnetic field surrounding a magnet is to draw field lines showing the direction of the magnetic field, in this method the strength of the field is shown by the number of lines.

Magnetic ______________ is the density of the field lines. Areas with many lines have _____________________ magnetic field strength.

**Example:**



**Magnetic Fields from Wires**

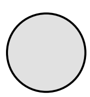
A wire with current flowing through it will create a magnetic field around it, to remember the direction of this field we use the

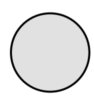
**First Right Hand Rule:**

Thumb:

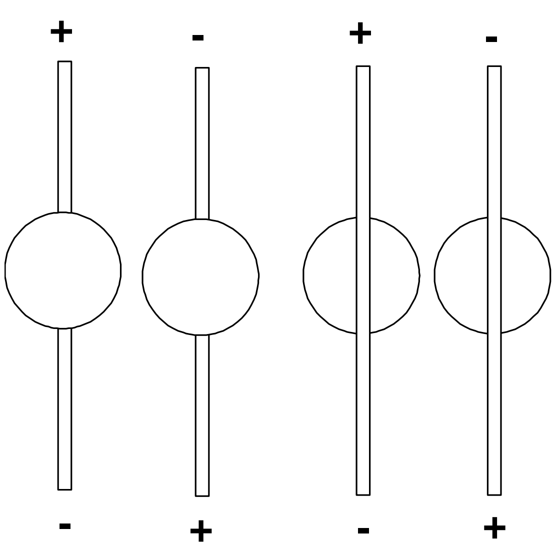
Fingers

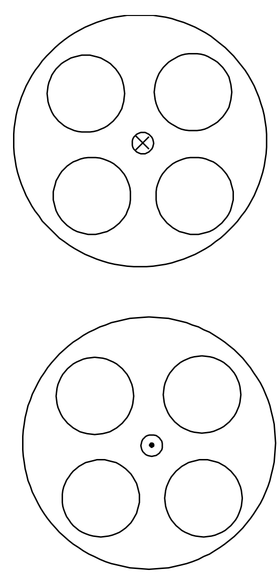
Often we will represent a current carrying wire as though you were looking at it end on. In this case we simply draw it as a circle. To indicate the direction of current flow we draw a ____ if it is in to the page and a ____ if it is out of the page.



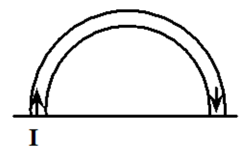
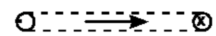


Fill in the following with the direction of the magnetic field



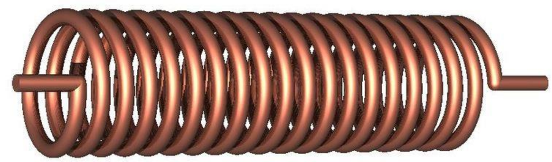
**Example:** Fill in the following with the direction of the magnetic field

| a) current flowing through wire into paper | b) curved wire |
| --- | --- |
|  |  side view  top down view |

**Example:** Determine the direction current is flowing in the following wires given the magnetic field generated by them.

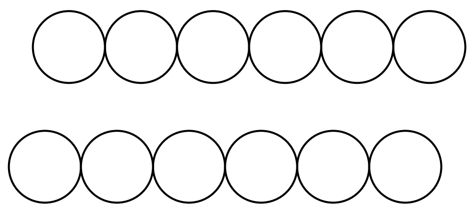
**Solenoids**: ___________________________

A solenoid is simply a ____________________________



https://commons.wikimedia.org/wiki/File:Solenoid-coreless.jpg

The many loops all carry current which each add to the _______________________________



Just as with a bar magnet a solenoid has

**<u>The 2nd Right Hand Rule:</u>**

Fingers: Thumb:

The magnetic field outside of a solenoid is _____________ and ____________________________

However the magnetic field inside the solenoid is ________________ and fairly _________________________.

Inside a solenoid we can approximate the strength of the field using the following equation. It is only perfectly true if the ________________ of the solenoid is much greater than its _________________, but is an acceptable approximation otherwise:

Where : B =

=

I =

n =

**Example:** A hollow solenoid is 25 cm long and has 1000 loops. If the solenoid has a current of 9.0 A what is the magnetic field in the solenoid?

**Magnetic Force**

With permanent magnets ___________________ poles attract and ___________________ poles repel each other.

Surrounding a current carrying wire there is a __________________________________________. So we will assume the wire will be affected by magnetic forces.

Two parallel wires carry current in the same direction. Will the wires attract each other or repel each other?

Two parallel wires carry current in opposite directions. Will the wires attract each other or repel each other?

**Wires in Magnetic Fields**

A current carrying wire in a magnetic field will experience a _______________________________________

A current carrying wire is placed between two permanent magnets as shown

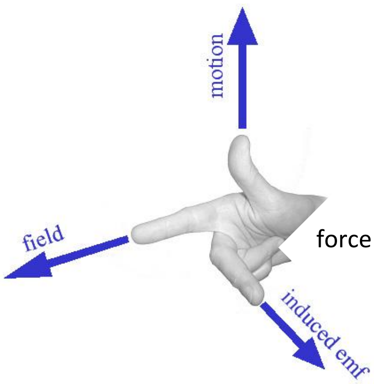

Above the wire, both the permanent magnetic field and the field generated by the wire point in the ______________ direction. These fields will ___________ each other.

Below the wire the permanent magnetic field and the field generated by the wire point in _______________________ directions. These fields will ____________ each other.

The result is a ______________ force from above the wire and an ____________ force from below the wire. The wire will move ___________________________________________.

**Example:** In which direction will the current carrying wire shown be pulled by magnetic force?

**The 3rd Right Hand Rule:**




The magnitude of the magnetic force on a conduction can be calculated as

Note that if the conduction is perpendicular to the magnetic field this formula becomes

If the conduction is parallel to the magnetic field then

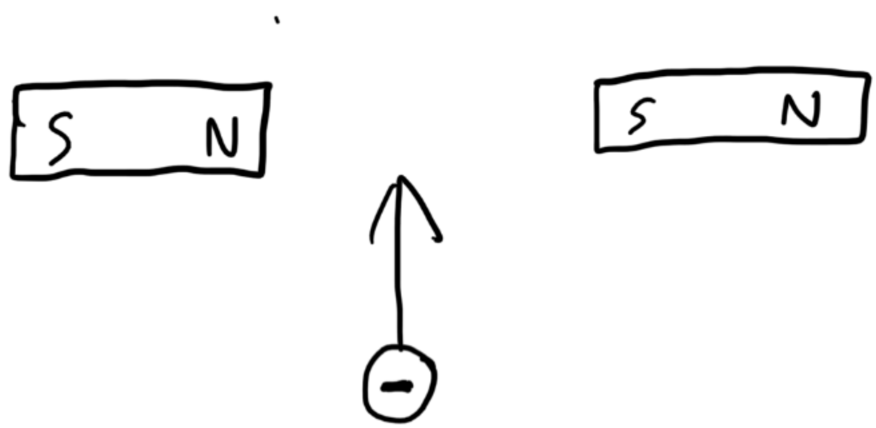
**Example:** Calculate the magnetic force on a wire of length 0.10 metres, which runs perpendicular to a magnetic filed of strength $6.2\times 10^{-2}\ T$, if there is a current of 1.2 A flowing through the wire.

**Moving Charges in Magnetic Fields**

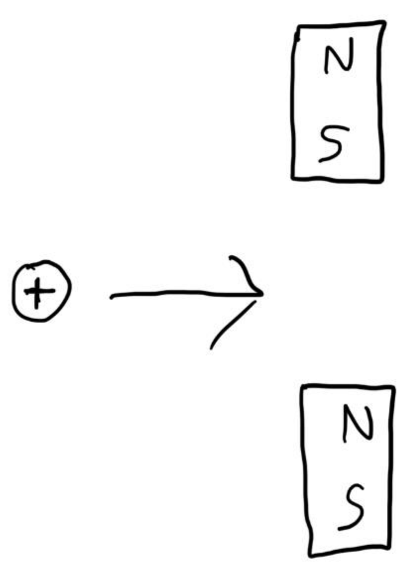
In the same way that charged particles moving through a wire will experience a force in a magnetic field so will charged particles.

To determine the direction the force acts on a particle we use the third right hand rule if the object is positively charged, and since it will be opposite if the object is negatively charged we use the same rule but with our left hand for negatively charged particles.

**Example:** In which direction will the negatively charged particle be pushed by the magnetic field?




**Example:** In which direction will the positively charged particle be pushed by the magnetic field?



The magnitude of force acting on a moving charged particle in a magnetic field can be found using the equation

**Example:** A +62 $\mu C$ particle is moving at 620 m/s perpendicularly through a magnetic field of strength 0.0056 T. What is the magnetic force being applied to the particle?

**Motors**

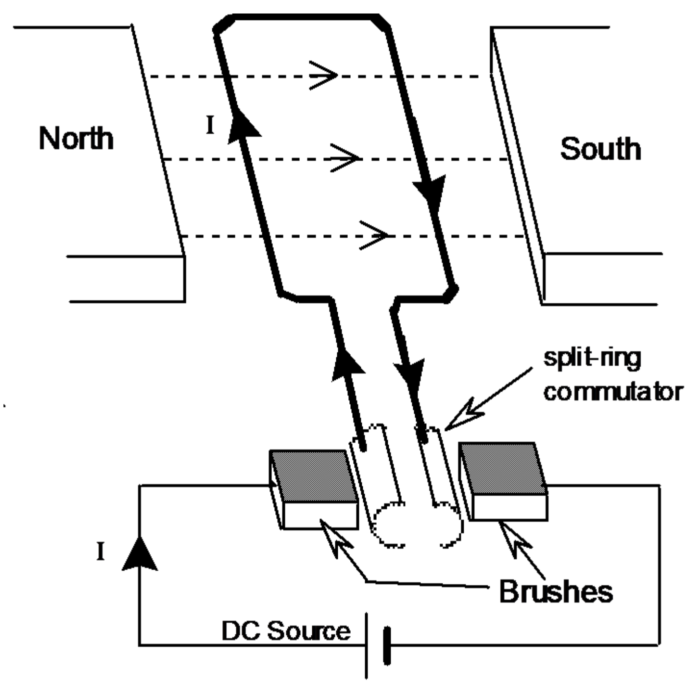
An electric motor converts ________________________ energy into ____________________ energy.

An __________________ sits between the opposite poles of a magnet. As a current travels through the armature it interacts with the magnetic field causing the armature to rotate

A real motor will have _______________ of loops of wire in the armature.

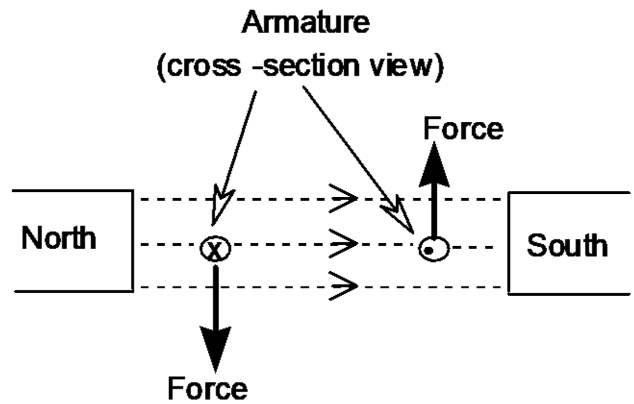
The ______________________ make electrical contact with the armature through the __________________________________.

Since the armature and commutator are rotating the brushes are usually spring loaded to keep them in firm contact with the armature.

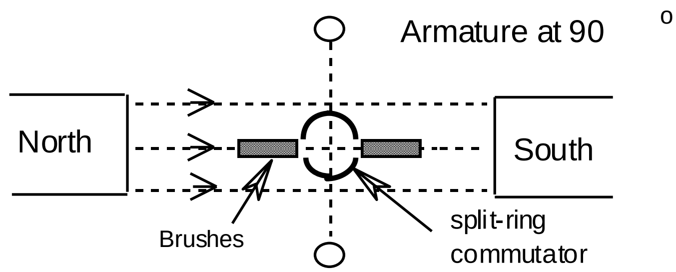


This is a cross section of the diagram from the previous page. When current flows through the wire the armature will rotate

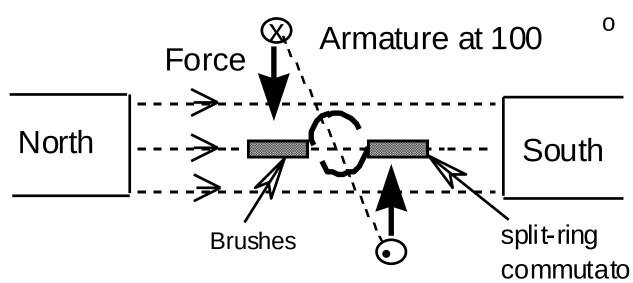
____________________________




Eventually the armature is turned 90 degrees, at this point there is no current because the "split" in the split-ring commutator is a non conductor. This means that there are no ____________________ acting on the armature, but its rotational _____________________ keeps it turning.




Once past 90° the current will change direction because the brushes are in contact with the _____________ section of the commutator. This change in current direction is fundamentally important because it ensures the armature always turns in the same direction.



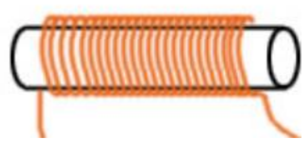
**Induction**

It was discovered that a wire with current flowing through it created a magnetic field, the next question was: Could a _________________________________ cause _________________ to flow in a wire?

Another way to say this is: Could a magnetic field generate an ____________________?

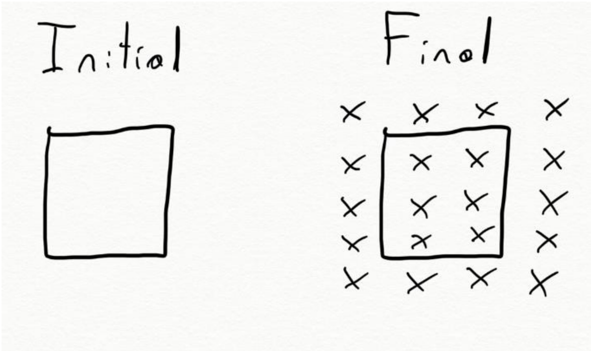
Michael Faraday discovered it was possible with a____________________________ magnetic field.

To determine the direction of the induced current we use Lenz's Law:



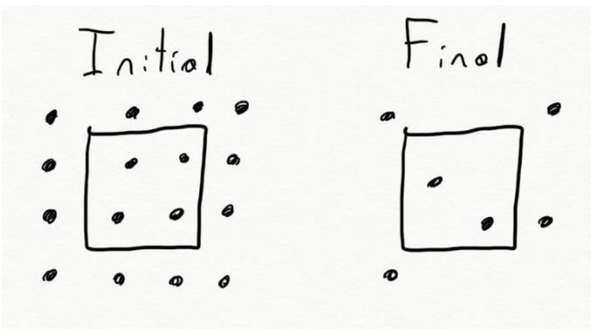
In order to calculate the EMF generated we need to use the idea of magnetic flux.

Magnetic Flux:



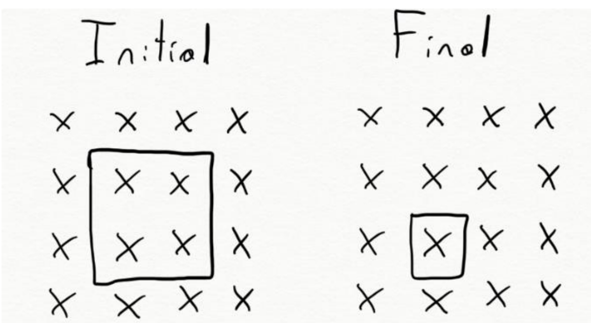

Change in Φ:

How to oppose:



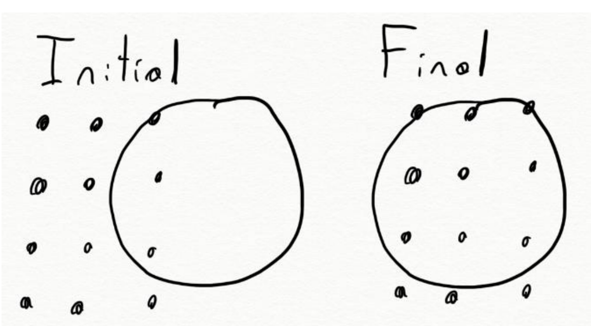

Change in Φ:

How to oppose:




Change in Φ:

How to oppose:




Change in Φ:

How to oppose:

Magnetic flux perpendicular to a magnetic field can be calculated as

**Example:** A square loop of wire is perpendicular to a 1.50 T magnetic field. If each side of the wire is 2.10 cm what is the magnetic flux through the loop?

The EMF is induced on a loop of wire by a changing flux

If there are several loops of wire the EMF generated by each loop adds together so total EMF is

**Example:** A circular loop of wire with radius 2.5 cm is placed in a magnetic field B=0.020 T into the page. The field is reduced to 0.010 T into the page in 0.10 seconds.

a) What is the average induced EMF?

b) Which direction does the current flow?

**Transformers**

A power plant might generate a certain amount of power and want to transmit to somewhere a long way away. Say a power plant generates a certain amount of electric power (P).

a) If it is transmitted at a voltage V, what is the formula for the current in the power line?

b) Some power will be lost to heat in the transmission line, if the total resistance is R write a formula for total power lost in the line.

c) Write a formula for power lost as a percentage of power sent.

d) The resistance of a power line is $6.43 \times 10^{-7}\ \Omega$ per metre. What will the total resistance be for a 100.0 km line?

e) If we generated 120 kW of Power at a plant, determine the percent of power lost as a percentage of power sent if it is sent at 120V

f) Determine the percentage of power lost as a percentage of power sent if it is sent at 1 200 V.

For long distance transmission it is important to have very high voltage, however having this high voltage in our homes would be very dangerous, so we need a method to change or _______________ the voltage.

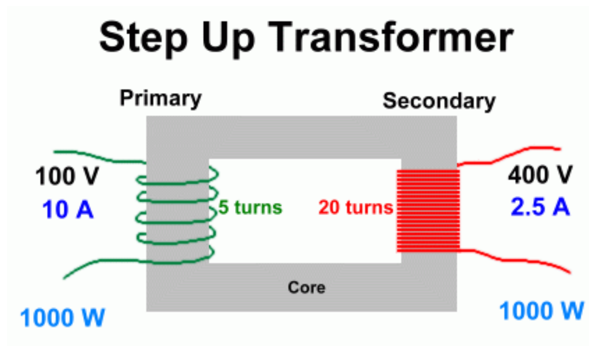
A transformer consists of a ______________________ coil and a _______________________ coil.

As current flows through the primary coil it produces a ________________ ________________. This magnetic field then induces an ____________________ _______________ in the secondary coil.

Transformers work for _____________ current.

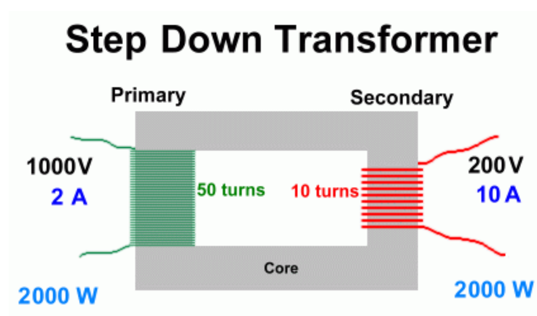
When a transformer increases voltage it is called a

A step up transformer has




When a transformer decreases voltage it is called a

A step down transformer has



To determine voltage change we use the formula

Though voltage is changed _____________________ is always conserved so _________________ is also conserved.

This gives us

Example 1: A step-up transformer is used to convert 120V to $1.50 \times 10^{4}$ V. If the primary coil has 24 turns, how many turns does the secondary coil have?

Example 2: A step-down transformer reduces the voltage from a 120 V to 12.0 V. If the primary coil has 500 turns and draws $3.00 \times 10^{-2}$ A,

a) What is the power delivered to the secondary coil?

b) What is the current in the secondary coil?