Gravity Analogies

q is analogous to m
$\underline{E}$ is analogous to g $F = mg$ $F = qE$

if you double q, you double the force, just the same as mass

$$F = k\frac{q_1 q_2}{r^2} \qquad F = G\frac{m_1 m_2}{r^2}$$

One can think of an electric field as a gravitational field.

<u>Differences</u> between gravitational & Electric fields:

1. Gravity can only create a pull, Electric fields can create a push or pull depending on charge
2. Electromagnetic force is degrees of magnitude larger than the gravitational force

So...
just as gravity in itself is not a force neither is $\vec{E}$

Both are a measure of "potential forces"

- That is $\vec{E} = \frac{F}{q}$ $g = \frac{F}{m}$. They are each a measure of <u>forces per unit charge</u> or <u>mass</u>
  - In order to have a force 2 bodies are needed both of these equations are the force equations with one mass or charge divided out

$$F = k\frac{q_1 q_2}{r^2} \qquad \vec{E} = k\frac{q}{r^2}$$

* $\vec{E}$ is the amount of force a charge will experience when put in that region of space next to the charge creating the $\vec{E}$ field

Gravity Analogies

See p. 17

Just as $\vec{E}$ is a "potential force" V is a "potential-potential energy"
- by potential-potential energy I mean the same as potential force
- $U = qV$ $\quad V = \frac{U}{q}$ ← Potential Energy / ← charge

* V is a measure of the amount of potential energy a given charge will have in a given region of space
- If the charge doubles so does its potential energy

$U = k\frac{q q_2}{r}$ $\quad V = k\frac{q}{r}$ Also the potential Energy with a charge divided out

remember

$U = mgh$ $\quad U = qV$ $\quad$ V is analogous to "gh"

Equipotential Lines
- These are lines which have the same V at every point on the line

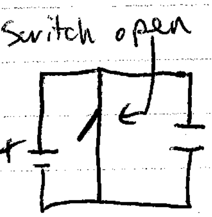
Capacitors ~~& Resistors~~

* A capacitor is something that stores energy by creating a charge differential

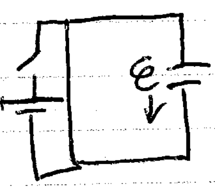
$Q = CV$ C is a measure of how much
$V = \frac{Q}{C}$ potential (energy) is stored per unit charge

With opposite charges deposited on 2 separated plates it creates an $\vec{E}$-field (a force), but does not allow the force to bring the charges together (to do work). This is Energy storage

Think of a dam. A dam creates a gravitational differential, but does not allow gravity to bring water down (do work). The energy is stored in the differential.



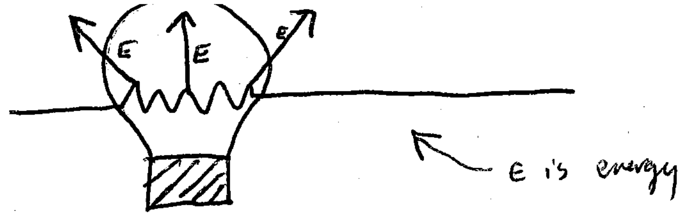
A capacitor stores V which is the same as an Emf. This means capacitors represent equilibrium conditions. In the circuit drawn at left the $\mathcal{E}$ source will charge up the capacitor until $V_{capacitor} = V_{Emf}$ in other words $\frac{Q}{C} = \mathcal{E}$. (Equilibrium)



When switch is closed & Emf is disconnected, the capacitor will now act as source of Emf driving current through the loop.
- This is important in understanding R-C circuits

A dielectric only means more potential is stored in the given capacitor per unit of charge

$Q = KC_0V$ if $K = 2 \rightarrow$ V is doubled per unit charge on capacitor
if $K = 3$ V is tripled, etc.



Resistors

- A current I is a movement of charge just like a river current is a movement of water (mass)

* A resistor is something which takes energy out of a circuit with current (like a light bulb).
- This is why IR is subtracted in current analysis (Kirchoff)

$V = IR \qquad R = \frac{V}{I}$

R is a measure of the amount of Energy used up per unit of applied current

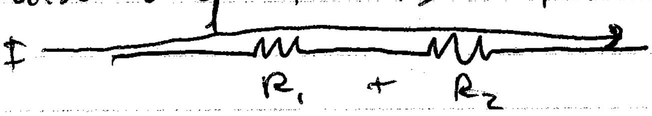
Kirchoff's rules

ΣI at a junction is 0 because q is conserved.
- If this were not 0, charge would build up in the junction & create a reverse Emf

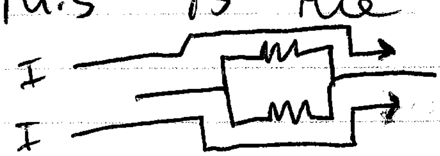
ΣV around a loop is 0 because electrostatic F is conservative

In Series vs. In Parallel (R_{eq})

In series resistances are added because I must go through each (only 1 path). This is also why I is the same for resistors in series

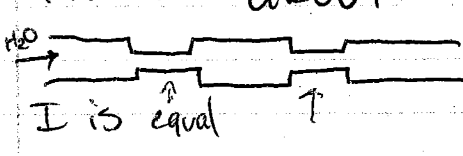


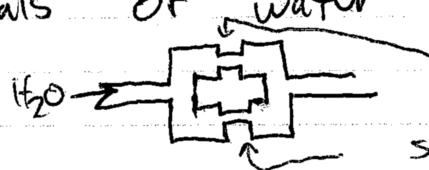
In parallel V is the same over each because this is the Emf. The full Emf is experienced in each resistor because I can take either path.



Think about canals of water to convince yourself

in series canal of H_2O





V is equal because it is a measure of strength of current

R-C circuits

- make sure you understand resistors & capacitors

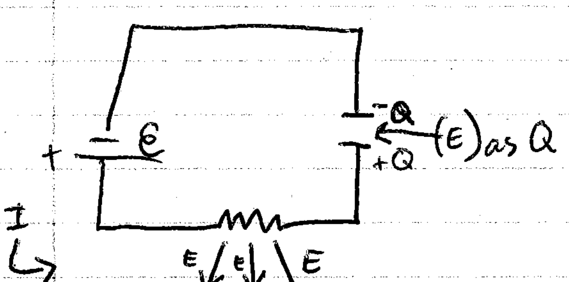
In an R-C circuit the capacitor is storing up energy and the resistor uses it up

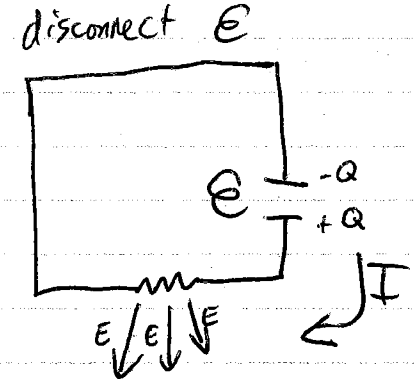
- This is cause of all time-dependencies
  - * The Capacitor cannot charge fully instantaneously because Resistor is using up some energy that is coming to the capacitor as I
  - At t = large (after awhile) Capacitor will be fully charged
  - * so when Emf is disconnected Capacitor becomes the source of Emf, directing I in the opposite direction as the original Emf
    - This sends a current around the circuit, which uses up energy as it goes through resistor

E = Energy here

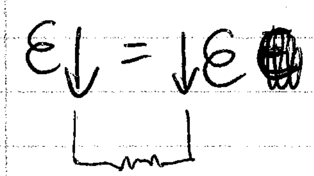
ε = Emf

t=0





I moves until V of capacitor is equal to ε creating an equilibrium



equal & opposite Emfs

$\vec{B}$

$\vec{B}$ fields are created & felt only by <u>moving</u> charges or currents

$F_{\vec{B}}$ is always a Force perpendicular (90° to) the <u>movement</u> of charge
- This makes it a <u>centripetal</u> <u>force</u> (remember $a_c = \frac{v^2}{r}$)

$F_B = \frac{mv^2}{r}$ $\quad\quad$ $F_B = q\vec{v} \times \vec{B}$

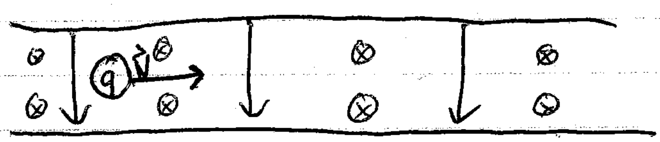
$F_B = F_B$ $\quad\quad$ $\frac{mv^2}{r} = qvB$ $\quad\quad$ $\boxed{R = \frac{mv}{|q|B}}$

radius of circle made by moving q in $\vec{B}$ field
- comes from equilibrium

For $\vec{E}$-$\vec{B}$ fields crossed ($\frac{q}{m}$ situation)(velocity selectors)

Force from $\vec{E}$ is equal & opposite to Force from B

$\vec{E}$ down
$\vec{B}$ into page



For charge q $\frac{\vec{E} \text{ force is}}{\vec{B} \text{ force is}}$ = no net force

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so $F_{\vec{E}} = F_{\vec{B}}$

$qE = qv \times B$

$v = \frac{E}{B}$ (q drops out like m in gravity problems)

or $E_{kinetic} = E_{electric\ potential}$

velocity → $\frac{1}{2}mv^2 = qV$ ← potential

$\frac{q}{m} = \frac{E^2}{2VB^2}$

potential, $\frac{E}{B}$ was substituted in for velocity

1 step missing from $V_{velocity} = \frac{E}{B}$