Lecture 2

28 January, 2013

Part I: Basic Electricity

- Prelude
- Atomic Stuff
- Voltage, Resistance, Current, Power, Energy
- DC Series Circuits
- DC Parallel Circuits
- AC Circuits in brief

Announcements (1/28/13)

- 401B and 501B:
  - Laboratory Meeting Tues Jan 29, 4^{00}-5^{00} pm
- Electricity Test in 2 weeks (Feb 11)
- Fill out and hand in 3x5 cards to Lauritz

Prelude: Scale of Measurement

- Deci = 10^{-1}
- Centi = 10^{-2}
- Milli = 10^{-3}
- Micro = 10^{-6}
- Nano = 10^{-9}
- Pico = 10^{-12}
- Fento = 10^{-15}

- Kilo = 10^{3}
- Mega = 10^{6}
- Giga = 10^{9}
- Tera = 10^{12}

Bits, Bytes, Mega, Giga, Tera (explained)
1 bit = a 1 or 0 (b)
4 bits = 1 nybble (?)
8 bits = 1 byte (B)
1024 bytes = 1 Kilobyte (KB)
1024 Kilobytes = 1 Megabyte (MB)
1024 Megabytes = 1 Gigabyte (GB)
1024 Gigabytes = 1 Terabyte (TB)

Foundations:

Basic Electricity
Basic Neurophysiology
Basic Neuroanatomy

What's a Trillion $ (Tera $)

http://www.pagetutor.com/trillion/index.html

Prelude: 3 Great Forces

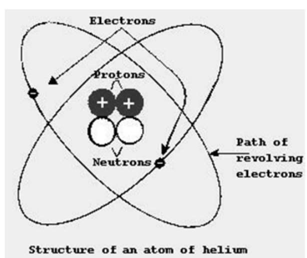
- Nuclear — Strong, very short (subatomic) distances …
- Electrostatic — Holds all kinds of stuff together in the everyday world
- Gravitational — Weakest, but impressive over very large distances and with large masses

Static Electricity

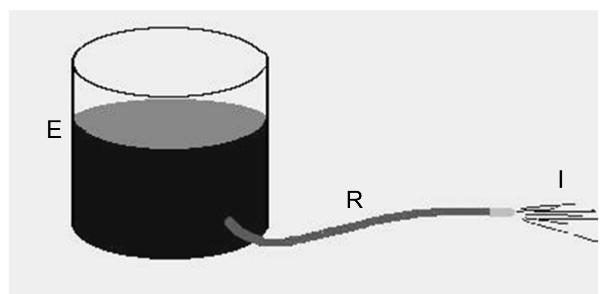
- Friction with Poor Conductors
- Electrons displaced from one substance to the other (e.g Hair to comb, carpet to body)
- Leads to voltage potential (i.e., difference)

Electrostatic Forces

- Due to charged subatomic particles
  - Proton
  - Electron
  - but not Neutron
- The Law:
  - Unlike Charges Attract
  - Like Charges Repel

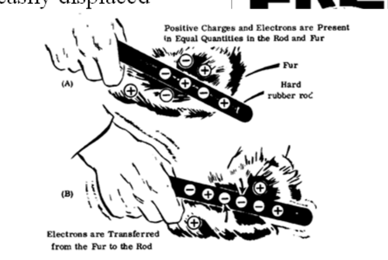


Basic Electricity by Analogy

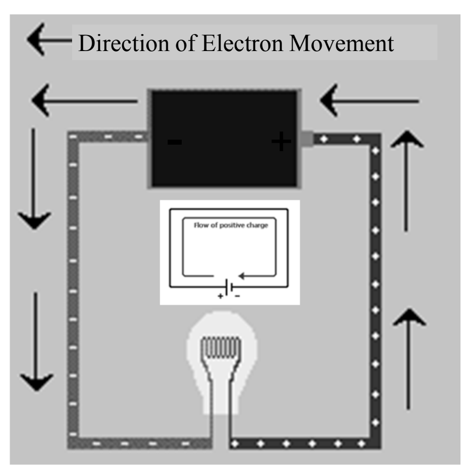


Free Electrons

- Some electrons can be easily displaced



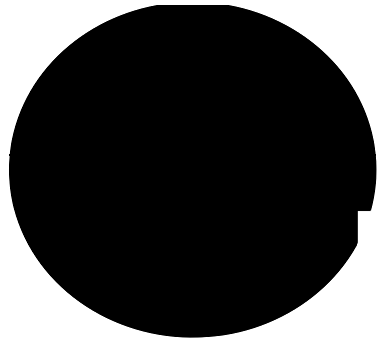
Demo



DC Anyway!

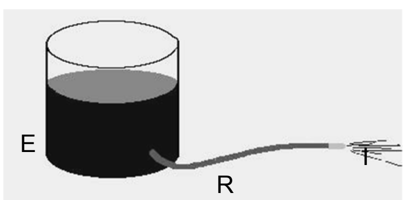
Details Details

Symbol	Term	aka	Unit
E	Voltage	Electromotive Force	Volts (V)
I	Current	Rate of Flow	Amperes (A)
R	Resistance	--	Ohm (Ω)
P	Power	Rate of work	Watt (w)
W	Energy	Ability to do work	Watt-Second (Joule)

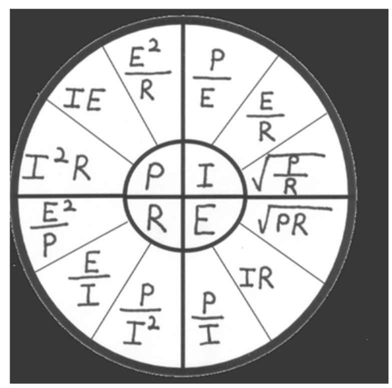


Ohm's Law

$$I = \frac{E}{R}$$
$$E = IR$$
$$R = \frac{E}{I}$$



See also: http://www.falstad.com/circuit/e-ohms.html



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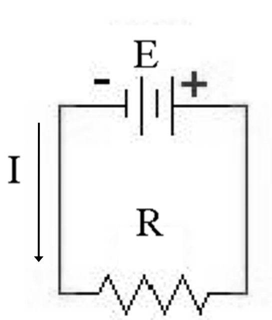
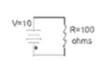
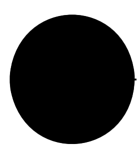
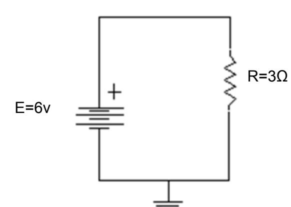




Basic Circuit



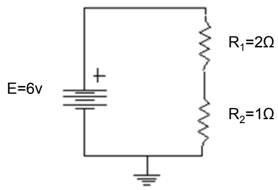


I = ?

Volt-Ohm Meter Demo

Series Circuit

$$R_T = R_1 + R_2$$



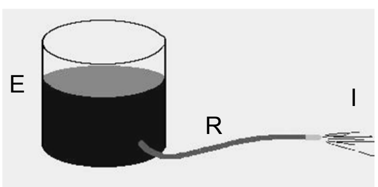
I = ?

E_{R1}=?

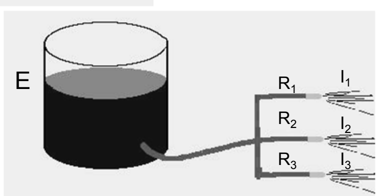
E_{R2}=?

Java Demo

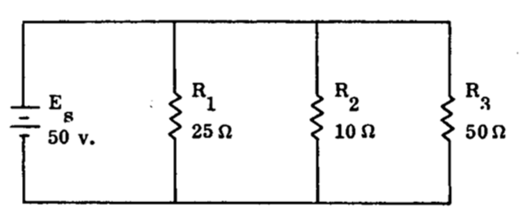
By Analogy: Series Vs Parallel



$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$



Parallel Circuit



R_T = ?

I_T=?

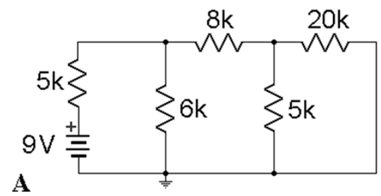
I_1=?

I_2=?

I_3=?

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Complex Circuits

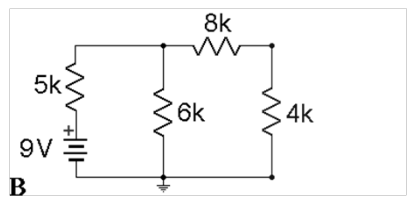


Find the current flowing in the circuit, and the voltage drops.

YIKES! Need to reduce. Start at the parallel combination of 20k and 5k resistors; it is replaced with its effective resistance of 4k [$1/R_{equiv}$ = 1/20 + 1/5 = 1/20 + 4/20 = 5/20 = 1/4].

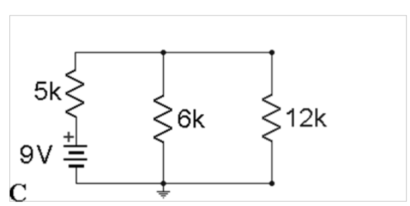
This and subsequent slides on this circuit adapted from: "http://www.physics.udel.edu/~watson/phys345/examples/effective-circuit.html"

Slightly less Complex Circuit



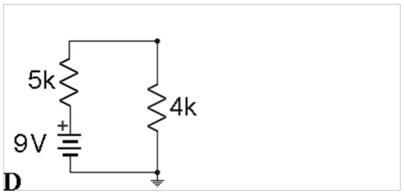
Looking Better. The effective resistance of 4k is in series with the actual resistance of 8k, leading to replacement by its effective resistance of 12k. [R_{equiv} = 4k + 8k]

Less Complex Still



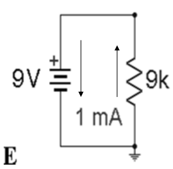
Better Still. Now there is a parallel combination of 12k and 6k resistors; it is replaced with its effective resistance of 4k [$1/R_{equiv}$ = 1/12 + 1/6 = 1/12 + 2/12 = 3/12 = 1/4].

Now Series: Almost Simple



Now we have a simple series circuit!
Finally, the equivalent resistance for the entire circuit is 9k.
[R_{equiv} = 4k + 5k].

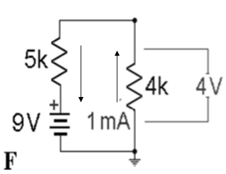
Now Series: Almost Simple



E

I = ?
[I = E/R = 9 V/9 k = 1 mA]

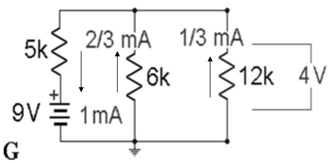
Working Back: Voltage Drops and Current



F

The real 5k resistor and the effective 4k resistance each have 1 mA of current since they are in series. Thus the 4k resistance has 4V of voltage difference across it (by Ohm's law).

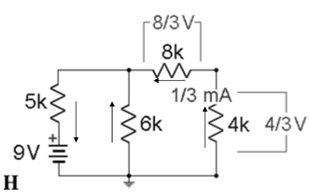
Working Back: Voltage Drops and Current



G

Breaking the 4k resistance into its component parts (in parallel), we find that 2/3 mA of current flows in the 6k resistor and 1/3 mA flows in the effective resistance of 12k.
I = E/R = 4/6K = 2/3 mA
I = E/R = 4/12K = 1/3 mA

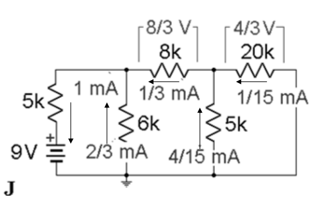
Working Back: Voltage Drops and Current



H

Breaking the 12k resistance into its component parts (in series), we find that there is 8/3 V across the 8k resistor and 4/3 V across the effective resistance of 4k.
E = IR = 4KΩ * 1/3 mA = 4/3 V
E = IR = 8KΩ * 1/3 mA= 8/3 V

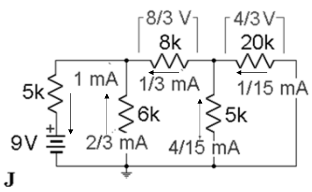
Working Back: Voltage Drops and Current



J

Finally, breaking the 4k resistance into its component parts (in parallel), we find that 1/15 mA of current flows in the 20k resistor and 4/15 mA flows in the 5k resistor.
I = E/R = (4/3V)/20KΩ = 4/60 mA = 1/15 mA
I = E/R = (4/3V)/5KΩ = 4/15 mA

Working Back: Voltage Drops and Current

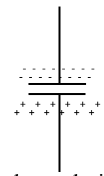


Summarizing:

1. Current through the battery?	1 mA
2. Current through the 8k resistor?	1/3 mA
3. Voltage difference across the 20k resistor?	4/3 V

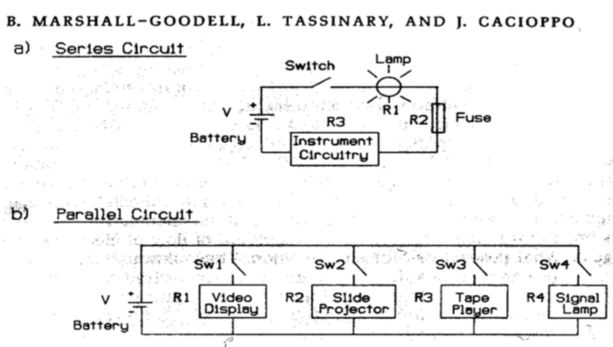
Capacitance

- Two closely spaced plates – offer essentially no resistance

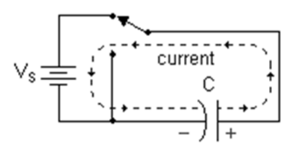


- As negative charge built up on first plate due to flow of electrons, a positive charge would build up on second plate
  - The current **charges** the plates of the capacitor, **but does not flow through the capacitor**, itself.

In Real Life…

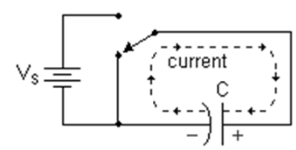


Capacitance

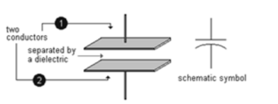


Charging – current flows until capacitor is fully charged, then stops

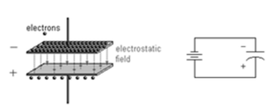
Discharging – current flows in reverse direction until capacitor fully discharged



Capacitance



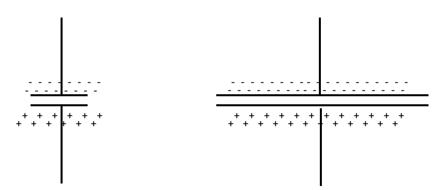
Capacitor = two conductors separated by a dielectric.
Dielectric = material that is a good insulator (incapable of passing electrical current), but is capable of passing electrical fields of force. Examples include glass, porcelain.



Charged Capacitor = more electrons on one conductor plate than on the other.

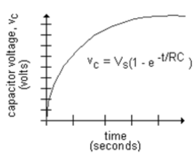
Capacitance – Size Matters

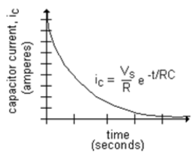
- Which has more capacity?



- More capacity, more current flows before capacitor is fully charged

Capacitor Time Constants



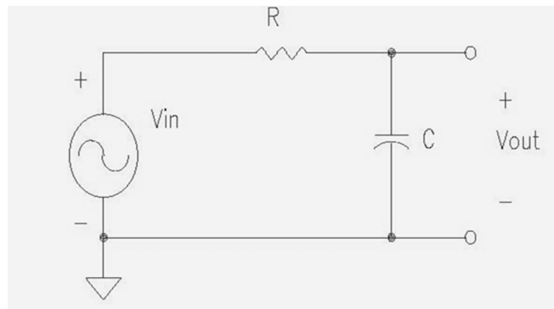


Over time…
Capacitor's voltage increases

Current flow grinds to a halt

The capacitor's time constant TC=
- The time in seconds for it to become 63.2% charged
- The time in seconds for current flow have slowed by 63.2% from its starting value

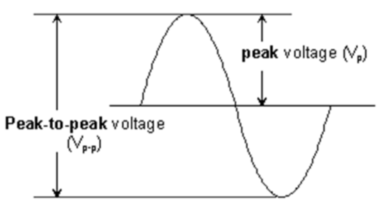
Using Capacitors to make Low Pass Filters



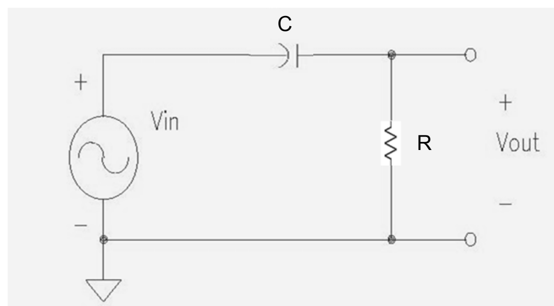
What will happen to fast signals; slow signals?

AC Circuits

- DC Circuit: Current Flow is unidirectional, from – to +
- AC Circuit: Current Flow switches direction periodically (at a given frequency in Hz)



Using Capacitors to make High Pass Filters



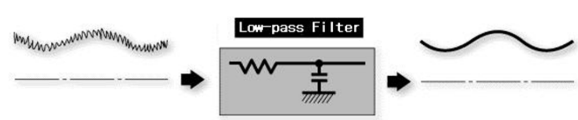
What will happen to fast signals; slow signals?

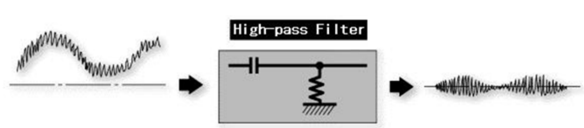
AC Circuits and Capacitance

- Slowly alternating signals
  - will fully charge capacitor, and signal will be impeded
- Rapidly alternating signals
  - will not fully charge the capacitor before the direction of flow reverses, allowing signals to pass unimpeded

http://micro.magnet.fsu.edu/electromag/java/capacitor/

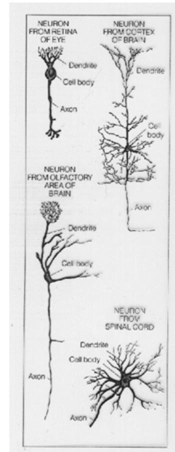
http://www.vjc.moe.edu.sg/academics/dept/physics_dept/applet/rc/rc.htm



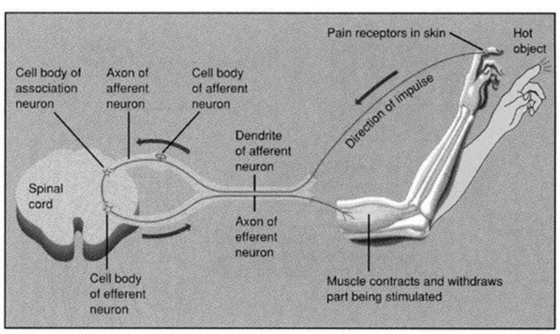


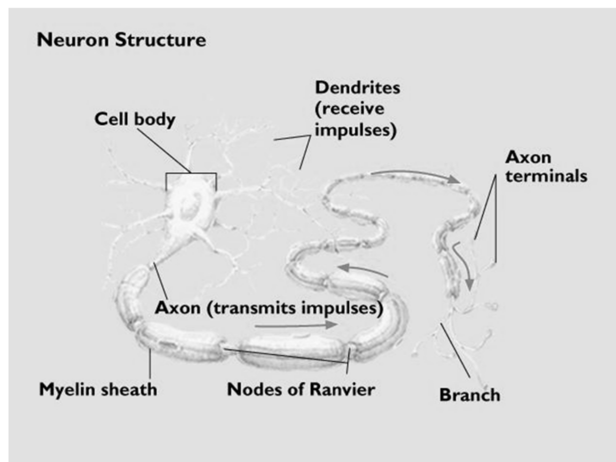
Part II: Basic Neurophysiology

- Three basic units inside the brain
  - Glial cells
  - Extracellular space: not really space
  - The neuron
    - <u>Three types</u>:
      - Sensory
      - Motor
      - Interneuron



Withdrawal Reflex



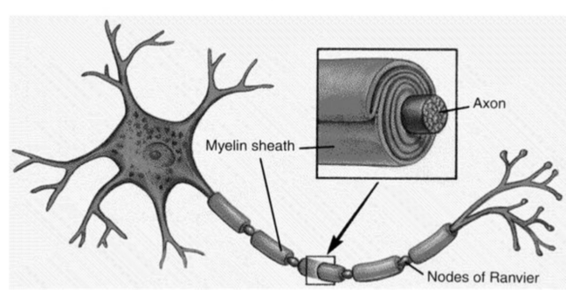


The Common Household Neuron

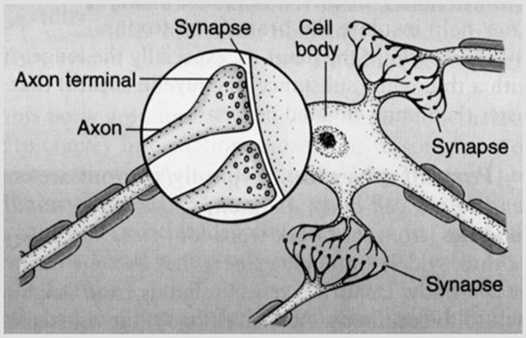
- <u>Vary widely</u>, but <u>all have</u>:
  - Cell body (soma)
  - Dendrites
  - Axon
    - <u>Myelin sheath</u>
    - Nodes of Ranvier
    - Microtubules
    - <u>Terminal buttons</u> (AKA synaptic knob)
- Nerve = a bundle of axons

Jump to Next

Myelin Sheath



The Synapse



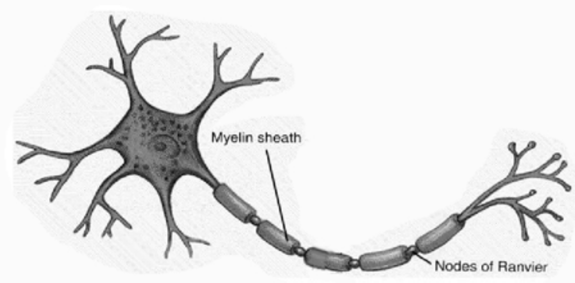
Axonal Conduction

- <u>Depolarization</u>
  - Threshold
  - Axon Hillock
  - Na ions rush in resulting in:
  - <u>Action potential</u>;
    - All or none phenomenon, high frequency
    - Afterpotentials; hyperpolarizing, depolarizing; slow frequency
    - <u>Changes in membrane permeabilities</u>
    - <u>Propagation</u>
- <u>Refractory period</u>

Jump to Next

Neural Communication

- Axonal Conduction (electro-chemical)
- Synaptic Transmission (chemico-eletrical)



Axonal Conduction

- <u>Resting potential</u>
  - Inside of cell slightly negative
  - Two forces act upon these ions
    - Concentration gradient--osmotic force
    - Electromotive force
  - Equilibrium potential:
    - $E_{ion} = (R*T/z*F) * \ln(Conc_{Ex}/Conc_{In})$
    - where R is gas constant, T is temperature, z is ionic valence, and F is Faraday's constant.
  - <u>The Hodgkin & Huxley Model</u>

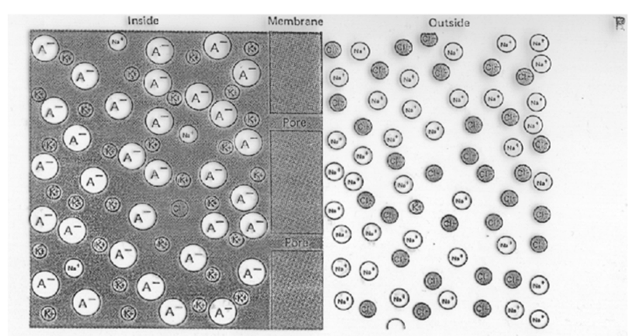
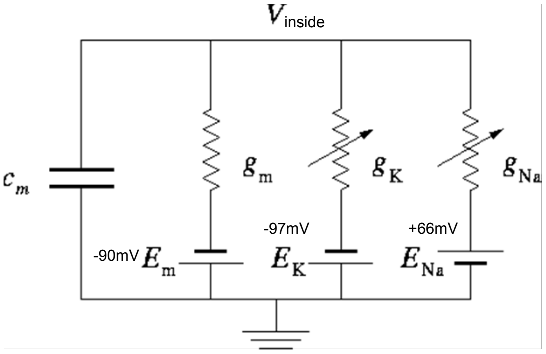
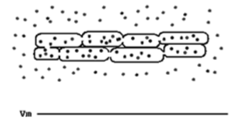
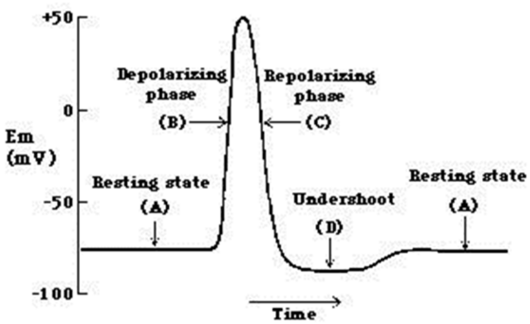


Fig. 2-3. Intra- and extracellular distribution of the ions. On both sides of the membrane, the different ions are indicated by *circles of different diameter*, proportional in each case to the diameter of the (hydrated) ion. A^- designates the large intracellular protein anions. The passages through the membrane, the "pores," are just large enough to permit the K^+ ions to diffuse through.



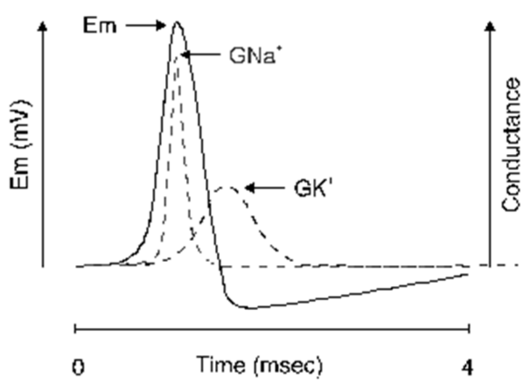
For interactive link: http://ssd1.bme.memphis.edu/icell/squid.htm

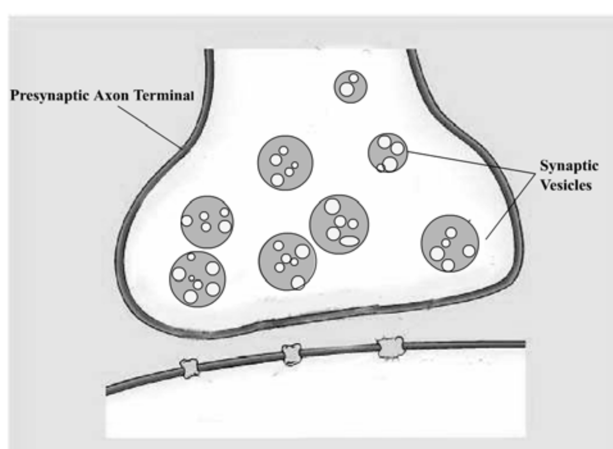




Synaptic Transmission

- Not an all-or-none phenomenon
- Synaptic gap or cleft at the synaptic junction
- Single axon splits near end--**terminal arborization**
- As action potential arrives
  - Synaptic vesicles migrate to cell membrane fuse and release
  - Neurotransmitters diffuse across the synaptic cleft
  - combine with **post-synaptic receptors**
  - When neurotransmitter binds to a receptor on the post-synaptic cell, a slow electrical potential (**post-synaptic potential**) is generated:
  - 5 to 20 mV at peak amplitude
  - 20-150 msec in duration (50 to 6 Hz)





Synaptic Transmission

- Post-synaptic potentials (PSP's);
  - Excitatory
  - Inhibitory
  - Interaction
- **Summation/Integration**
  - **temporal**
  - **spatial**
  - **decremental conduction** on dendrites and soma
  - axon hillock is critical area at which threshold must be reached
- After release of neurotransmitter,
  - reuptake
  - degradation
- **Functional Synaptic Units**

Jump to Next

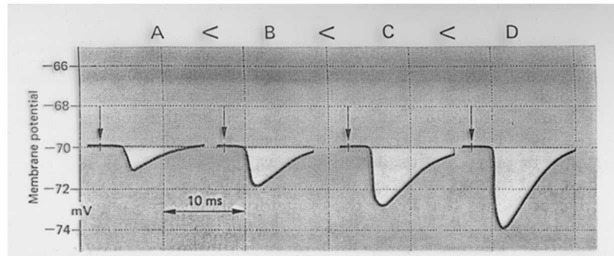
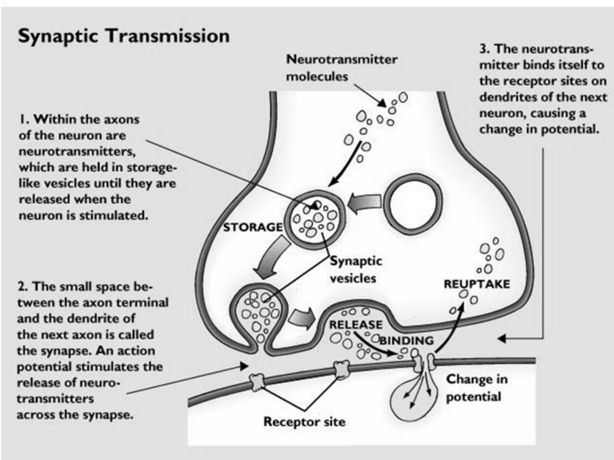


Fig. 3-11. Inhibitory postsynaptic potentials. Experimental arrangement as in Fig. 3-10, except that here an antagonist nerve is stimulated.



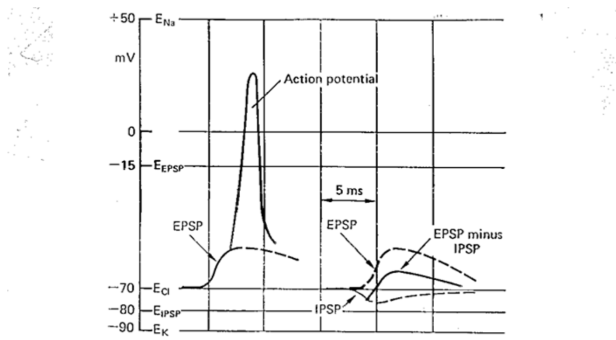
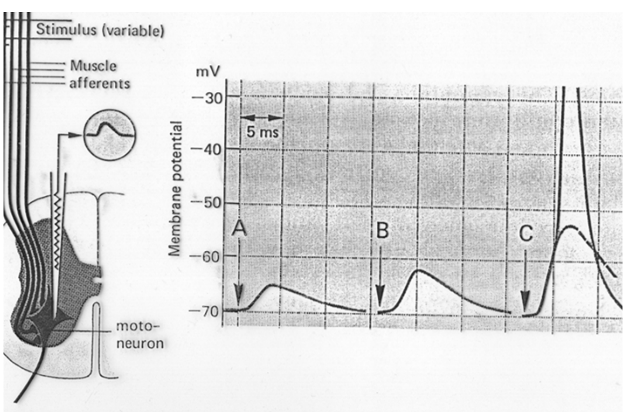
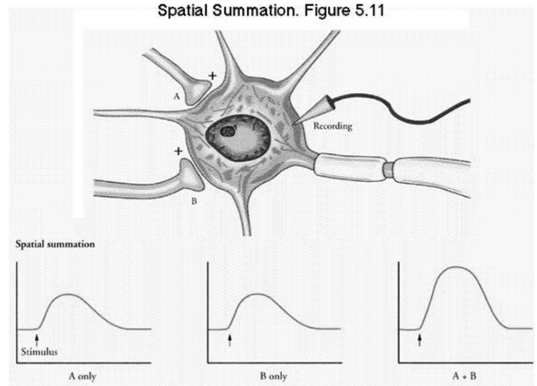


Fig. 3-14. The effect of an IPSP on the action potential; experimental arrangement as in Fig. 3-13. The homonymous nerve is stimulated strongly enough to produce a suprathreshold EPSP (*left*). On the *right*, the antagonist nerve is stimulated about 3 ms before the homonymous nerve. The equilibrium potentials of Na^+, K^+, Cl^-, EPSP, and IPSP are shown.



3-10. Excitatory postsynaptic potentials, recorded intracellularly from a mot
afferents in the peripheral nerve from the associated muscle are stimulated el

Spatial Summation. Figure 5.11



Temporal Summation. Figure 5.11