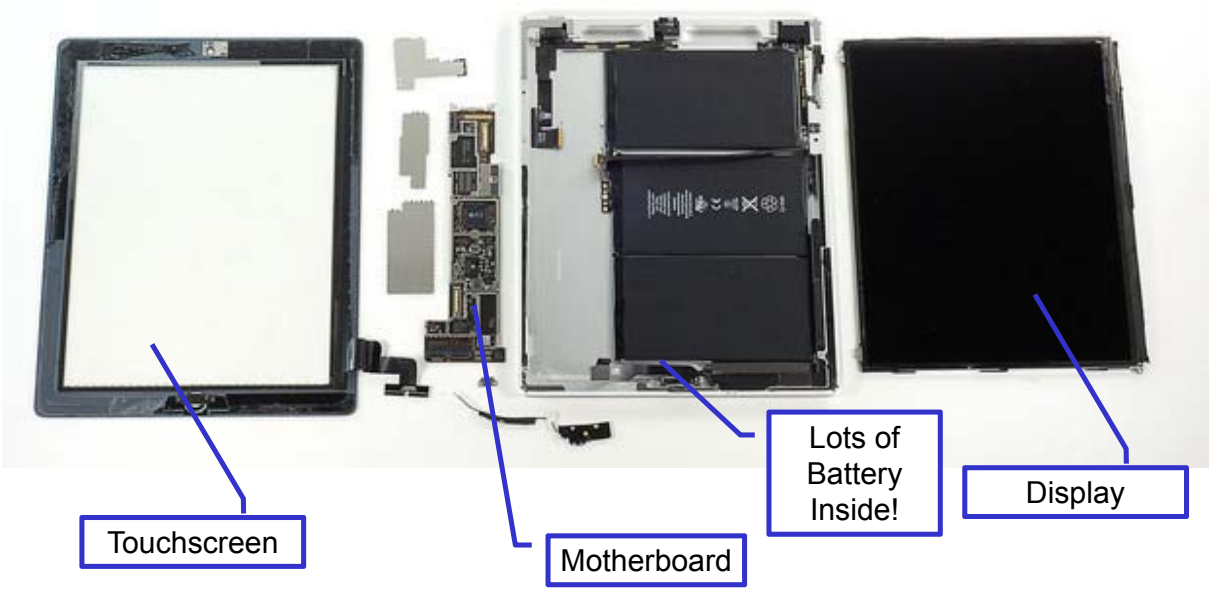
Touch Screen Technology

Topics covered:

1) Resistance, Capacitance, Charge, Voltage, and Current
2) Introduction to simple circuits

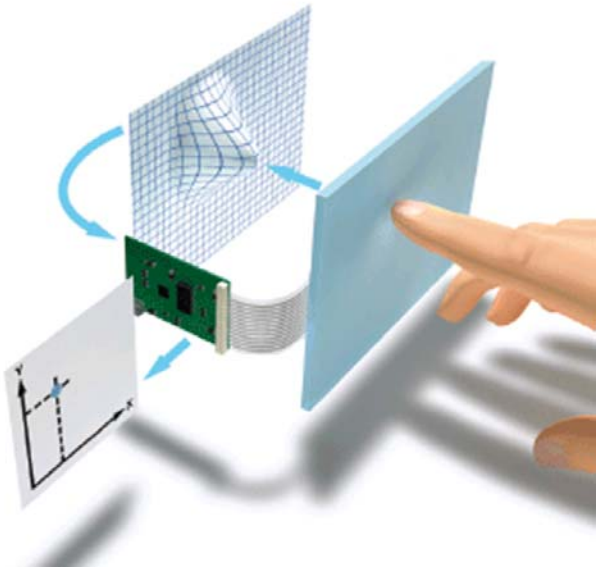
Taking apart a tablet

- For example, an iPad2

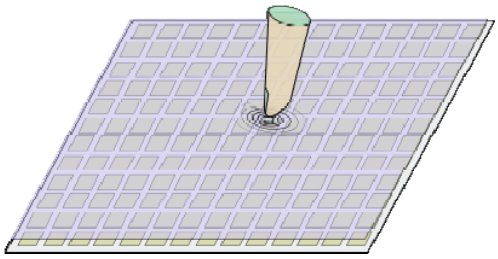


Touch Screen Overview

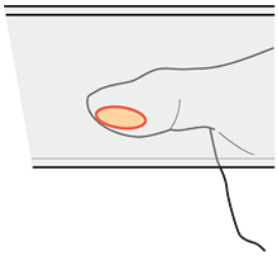
Finger touches the touch screen



The finger position is reported to the UI



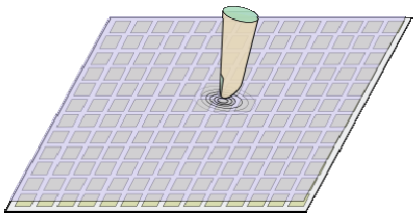
An arrayed sensor detects some electrical interaction

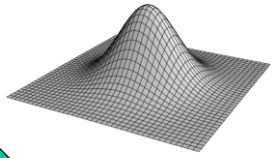


Fitting algorithms are used to calculate finger position

Sensed Touch as an image

An “image” of the arrayed sensor response is created





0	1	2	1	0
1	3	5	3	1
2	5	9	5	2
1	3	5	3	1
0	1	2	1	0

Apply filter to smooth noise

Used “differential” masks to detect edges

(1) Smooth the input image ($\hat{f}(x,y) = f(x,y) * G(x,y)$)

(2) $\hat{f}_x = \hat{f}(x,y) * M_x(x,y)$

(3) $\hat{f}_y = \hat{f}(x,y) * M_y(x,y)$

$$M_x = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

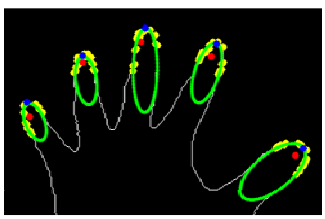
(4) $magn(x,y) = |\hat{f}_x| + |\hat{f}_y|$

(5) $dir(x,y) = \tan^{-1}(\hat{f}_y / \hat{f}_x)$

$$M_y = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

(6) If $magn(x,y) > T$, then possible edge point

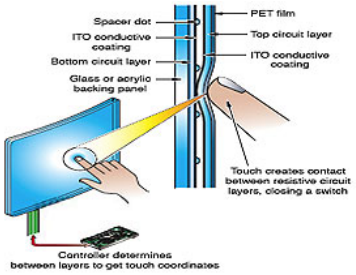
Best fit ellipses are defined for each touch and centroids are sent to the UI



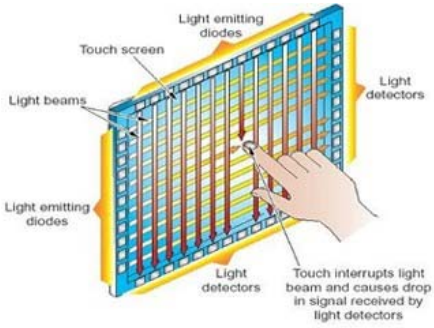
What we'll learn in this module

- We'll use the touch screen example to review fundamental electrical quantities (voltage, charge, current) and elements (resistors, capacitors, voltage)
- We'll analyze and design some resistor and capacitor-based circuits
- We'll get an early preview of sensing circuitry and introduce amplifiers
- Useful videos for review and extra information:
- http://www.ntspress.com/publications/circuits-second-edition/circuits-2e-faculty-resources/circuits-videos-from-berkeleys-ee-40/

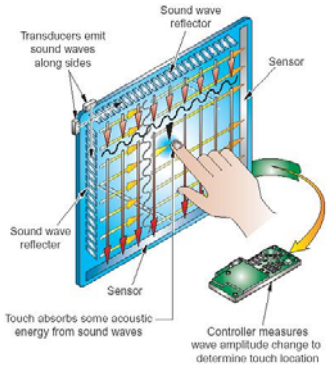
Main types of touch screens



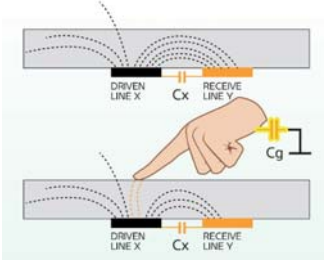
Resistive Touch Screens: Finger pressure makes an electrical contact in a circuit



Optical touch screen: Finger contact blocks light traveling from edges of screen



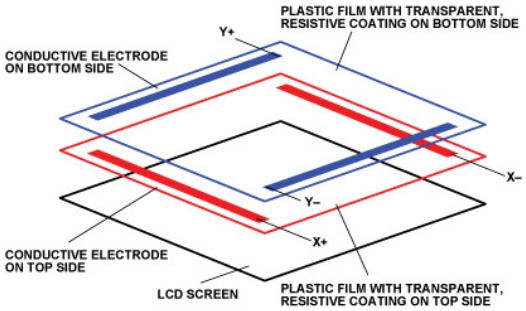
Acoustic touch screen: Finger alters sound waves traveling on screen surface

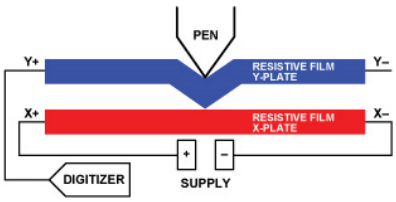


Capacitive touch screen: Finger alters the capacitance of the touch position

Resistive Touch Screen

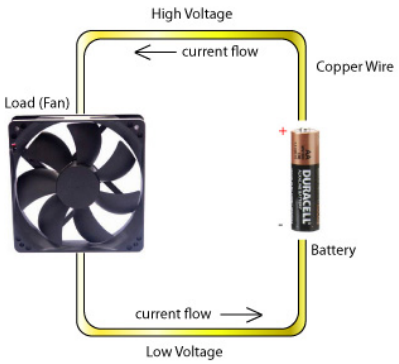
- Finger pressure "shorts" a specific location of a top layer to the bottom the bottom layer
- The entire bottom layer then becomes biased at the top layer touch-point potential
- We can explain operation by modeling this as a voltage divider
- To begin, we'll review voltage, current, and resistance

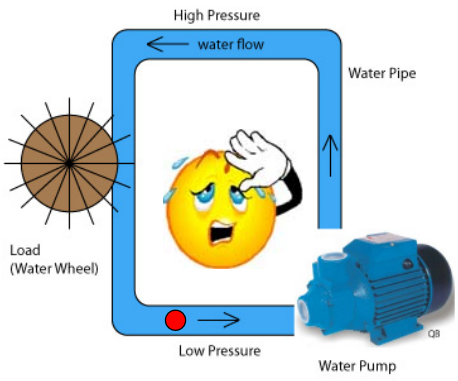




Reminder: Voltage

- Voltage is analogous to pressure in a water delivery system

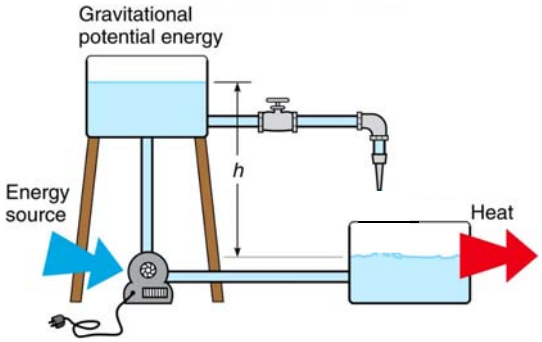




- Reminder: The change in voltage is defined as the work done per unit charge against the electric field.
  - Pushing a water droplet against the pump-induced flow is hard to do
  - If we push the droplet up, and then let it go, it quickly goes back down, turning the water wheel
  - Similarly, an electron on the negative end of the battery flows through the wire to the positive end, spinning the fan

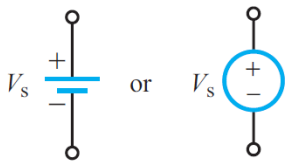
Work

- Reminder: The change in voltage is defined as the work done per unit charge against the electric field.
- In other words, we are building up potential energy

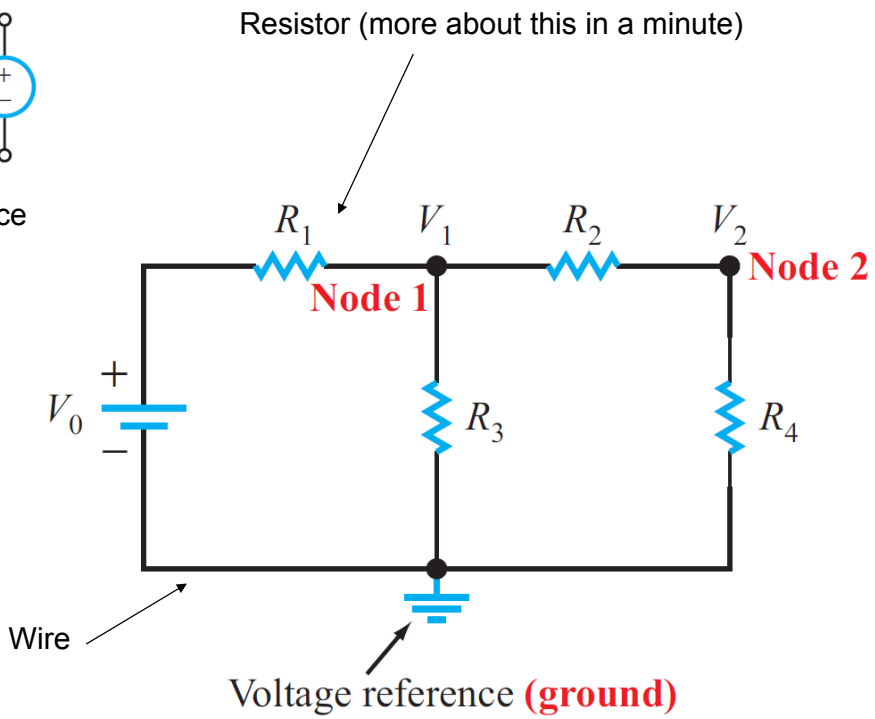


- When current flows, this is converted to kinetic energy
- What happens to the kinetic energy when the water "stops" as it hits the reservoir?

Representing Circuit Components

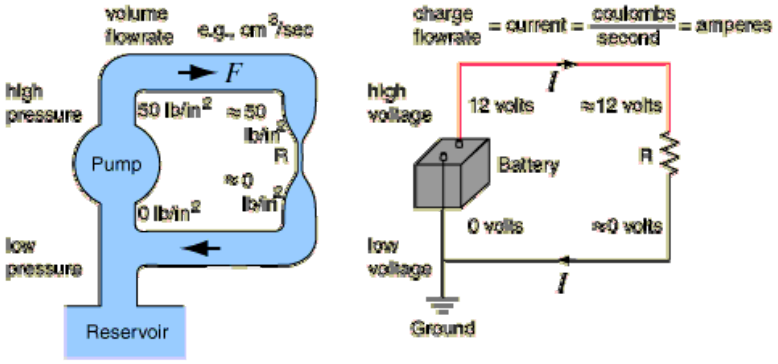


Voltage Source



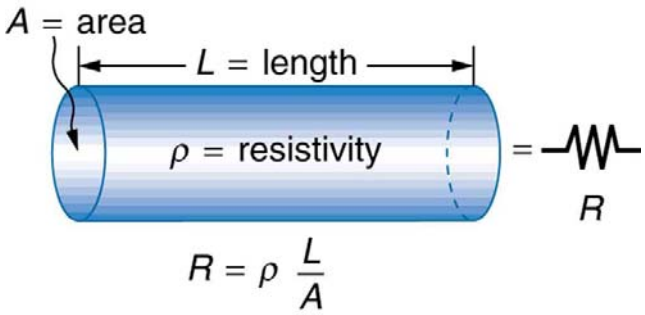
Voltage, Current, and Resistance

- Current is the “flow” of electrons
- The driving force for the “flow” is the voltage
- Resistance represents the “fight” the flow path imposes against the flow
- Resistance is:
  - Denoted by: 
  - Has units of ohms (Ω)



Resistance

- The resistance of an object is a function of its:
  - Length: longer is more resistive
  - Cross-sectional area: Wider is less resistive
  - Resistivity: A fundamental material-dependent parameter



Material	Resistivity[a] (Ω · m)
Silver	1.59×10^{-8}
Copper	1.7×10^{-8}
Gold	2.44×10^{-8}
Aluminum	2.82×10^{-8}
Tungsten	5.6×10^{-8}
Iron	10×10^{-8}
Platinum	11×10^{-8}
Lead	22×10^{-8}
Nichrome[b]	1.50×10^{-6}
Carbon	3.5×10^{-5}
Germanium	0.46
Silicon	640
Glass	10^{10} to 10^{14}
Hard rubber	$\approx 10^{13}$
Sulfur	10^{15}
Quartz (fused)	75×10^{16}

- Question: why is the resistivity of a material described in units of Ω·m?

Conductance

- Conductance is the reciprocal of resistance
- Conductivity has a unit of Siemens (S)

	Material	Conductivity (σ), S/m
Conductors	Silver	$6.17 \cdot 10^7$
	Copper	$5.8 \cdot 10^7$
	Aluminium	$3.82 \cdot 10^7$
	Iron	$1.03 \cdot 10^7$
	Carbon (graphite)	$1.0 \cdot 10^5$
	Water (sea)	4
	Water (fresh)	10^{-3}
Insulators	Water(distilled)	$2 \cdot 10^{-4}$
	Porcelain	10^{-10}
	Glass	10^{-10}
	Air	-
	SF_6	-

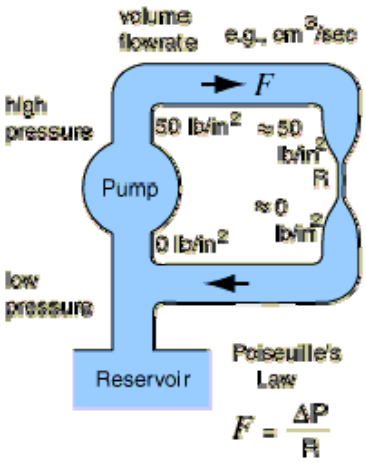
Useful Videos

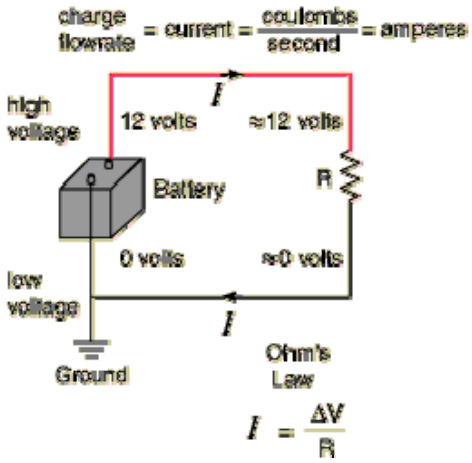
- Introduction: http://youtu.be/km2Ar7HWexQ
- Charge and Current: http://youtu.be/4z5cYzacZk8
- Charge, Current and Voltage: http://youtu.be/YqiW-c9vHl8

Ohm's Law

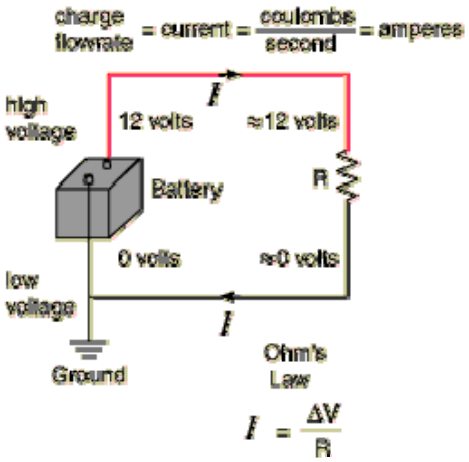
- Ohm's law describes the relationship between voltage, current, and resistance:

  $V = I \cdot R$



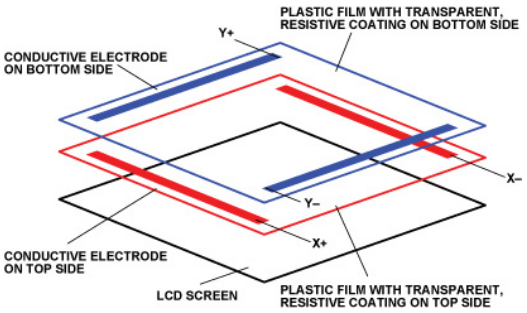


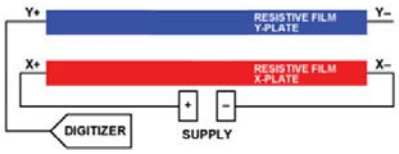
Questions: Ohm's Law



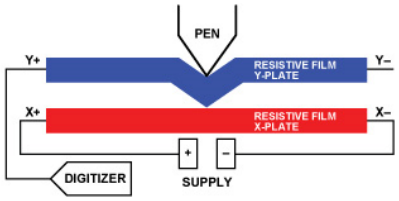
- Why is the voltage at the top of the resistor ~12V?
- Why is the voltage at the bottom of the resistor ~0V

Detecting Touch: Simplest View





No touch: No connection between plates – "Open" Circuit



Touch: Highly conductive connection between plates – "Short" Circuit

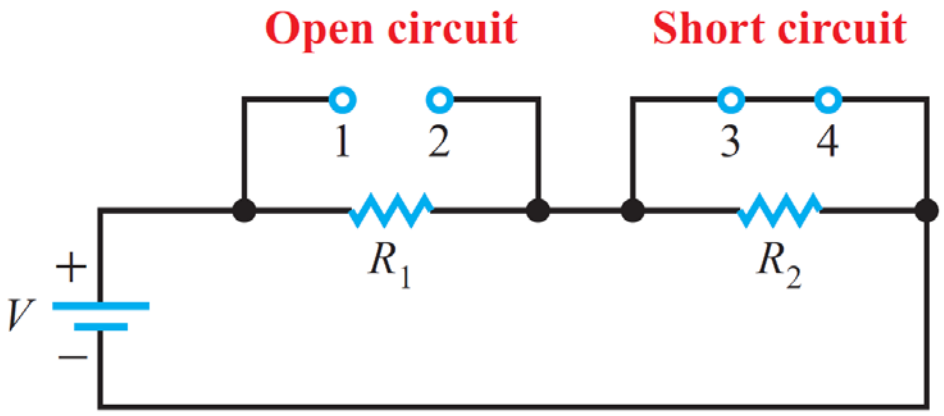
Open Circuits & Short Circuits

Open circuit: no path for current flow

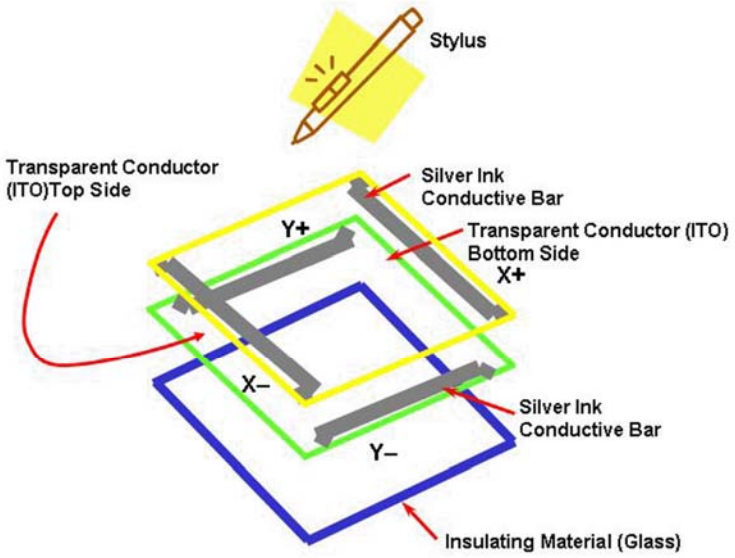
$R = \infty$

Short circuit: no voltage drop

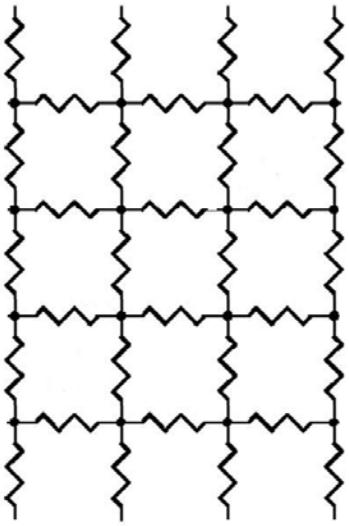
$R = 0$

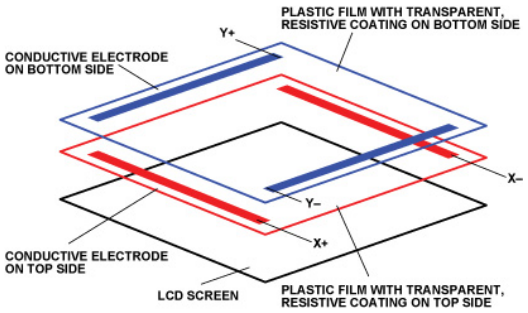


How can we model the resistor plates?



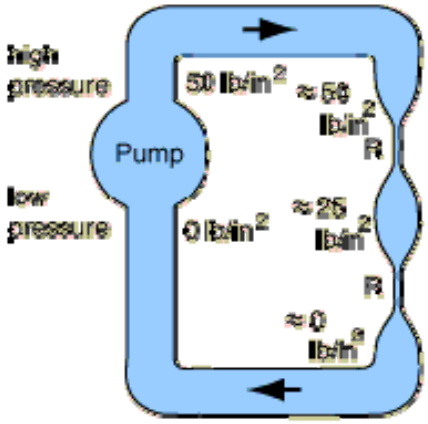
But it is a 2D sheet....

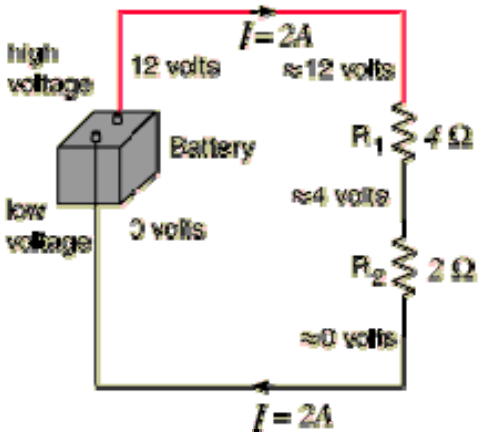




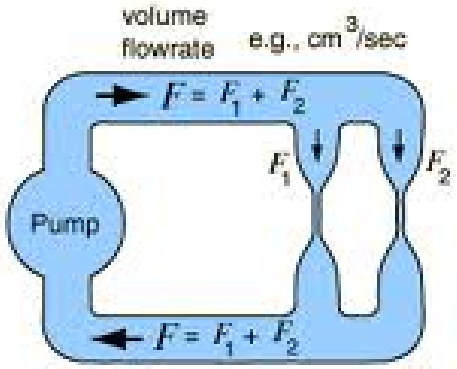
What about the conductive stripes?

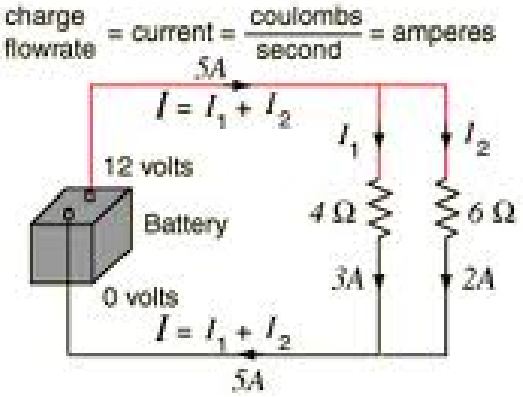
Question: What about 2 resistors in series?





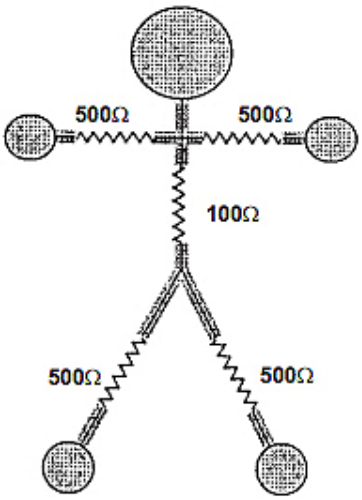
Question: … and in parallel?





Exercise: Household Wiring & Safety

- To begin: Here is a simplified model of the human body resistance
- We need to add in the resistance of the skin contact:
  - Dry: ~100kΩ
  - Wet: <1kΩ
- Q1: What is the resistance for a person touching a wire?
- Q2: On average, men have lower resistance than women. Why?



Exercise: Household Wiring & Safety

- The internal resistance of a plug is <0.5Ω. How should we model the circuit for a human touching an exposed wire at the plug by mistake?
- What is the voltage the human sees?

Exercise: Household Wiring & Safety

- Develop a model for a human touching an insulated wire.

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Silver	1.59×10^{-8}
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