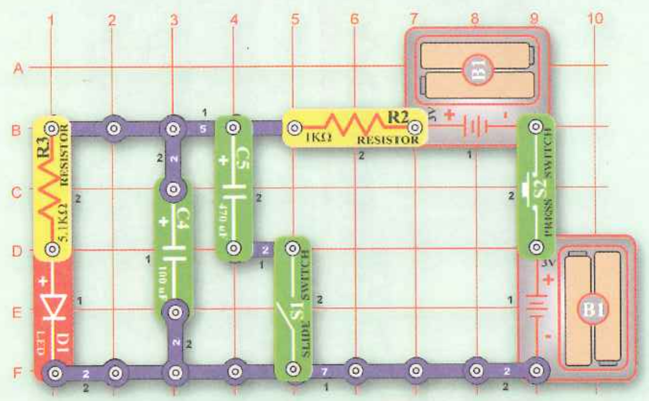
4-3 Capacitors in Series & Parallel

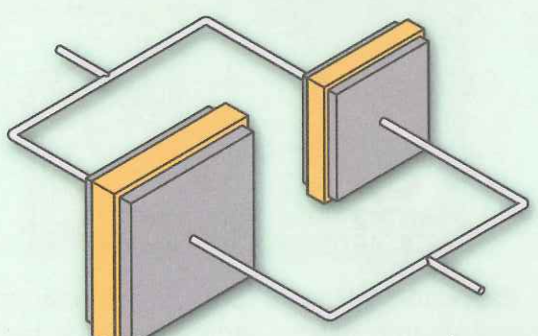
Experiments

Now consider this circuit (which is project 165):

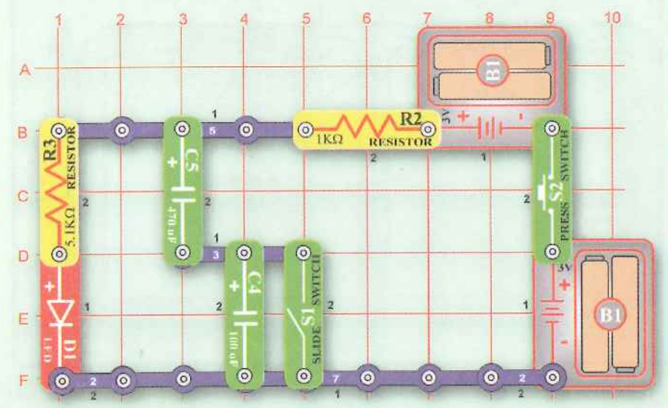


When the press switch is pressed there is a small delay before the LED gets bright, as the capacitor charges up. When the press switch is released there is a delay before the LED goes off, as the capacitor discharges. If the capacitors were removed from this circuit, the LED would be bright whenever the press switch is on. The capacitors slow down this circuit, by delaying the full effects of the press switch.

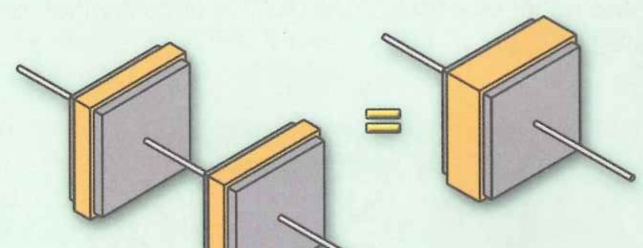
The LED delays will be much longer and easier to see if the slide switch is on, because then the larger 470μF capacitor is also in the circuit. When capacitors are placed in parallel like this, the overall capacitance is increased because there is more room to store electric charge in.



Now consider this circuit (which is project 164):



If the slide switch is off, both capacitors are in the circuit. This circuit is just like the last one except that now the slide switch is used to place the two capacitors in series. When capacitors are in series like this, the overall capacitance is decreased because this is like increasing the dielectric thickness. In terms of water pipes, you could think of capacitors in series as adding together the stiffness of their rubber diaphragms.



Two capacitors in series equals one capacitor with a thicker dielectric.

Notice that how capacitors combine is opposite to how resistors combine. **When parts are placed in series, resistance increases but capacitance decreases. When parts are placed in parallel, resistance decreases but capacitance increases.**

Advanced students can compute the total capacitance as follows:

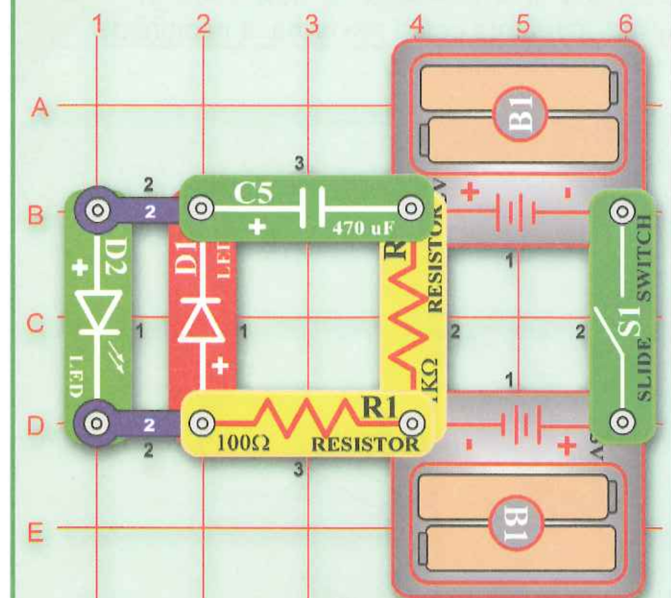
$$C_{parallel} = C1 + C2 + C3 + \ldots = \frac{1}{C_{Series}} + \frac{1}{C1} + \frac{1}{C2} + \frac{1}{C3} \ldots.$$

For example, a 100μF and a 470μF in parallel act like a 570μF. A 100μF and a 470μF in series act like an 82μF.

The total parallel capacitance is greater than the biggest capacitor, and the total series capacitance is smaller than the smallest capacitance.

Experiments

Now consider this circuit (which is project 296):



In this circuit the 470μF capacitor is placed backwards, its + side should normally be towards the higher voltage at the batteries. While the switch is on, current will flow and light the green LED even after the 470μF is charged up. This is because high-value capacitors "leak" when they are placed in a circuit backwards. The lower value parts will leak much less or not at all. If the 470μF was flipped around (so the "+" is on the right), then no current will flow after it charges up.

This circuit also demonstrates how LEDs allow current to flow in only one direction. The green LED flashes bright when the 470μF charges up, and the red LED flashes when the 470μF discharges.

Summary

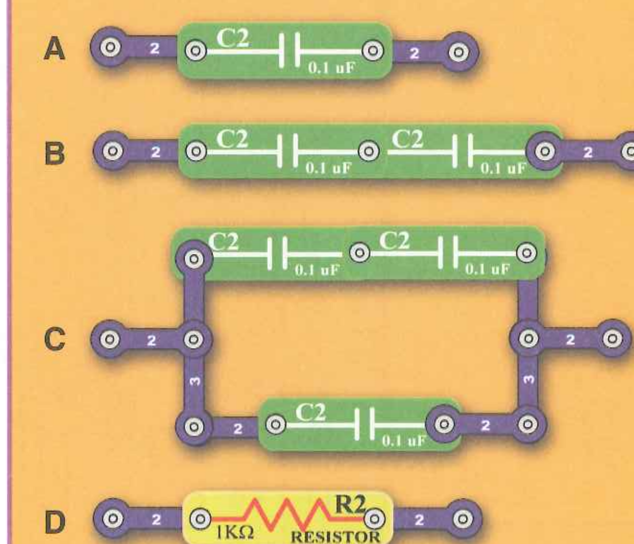
Summary of Chapter 4:

1. Capacitors are components that can store electricity for periods of time.
2. Capacitance measures how much electrical charge may be stored in a capacitor, and is usually expressed in microfarads (μF).
3. Capacitors block slow changing voltages and pass fast changing ones.
4. Capacitor charge/discharge times are proportional to the resistance and capacitance in the charge/discharge paths.
5. Placing capacitors in series reduces the capacitance, and placing capacitors in parallel increases the capacitance.

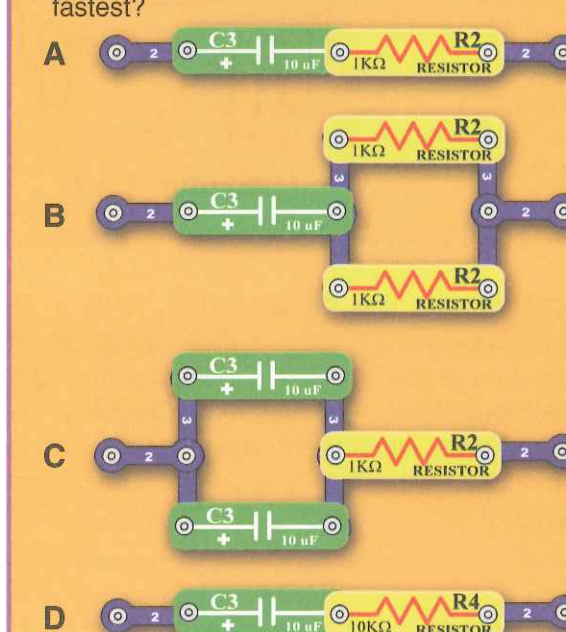
Quiz

Chapter 4 Practice Problems

1. A __________ is charged by having a one-way current flow through it.
   A. Faraday
   B. Capacitor
   C. Resistor
   D. Dielectric
2. Capacitor characteristics are controlled by . . .
   A. the material used.
   B. the number of metal-dielectric layers.
   C. the thickness of the dielectric layers.
   D. all of the above.
3. Which of these sub-circuits will have the highest total capacitance?



4. Which of these sub-circuits will charge up the fastest?



Answers: 1. B, 2. D, 3. C, 4. B