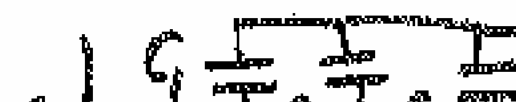
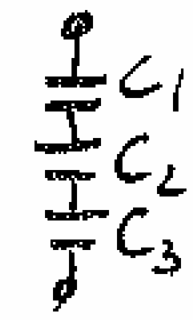
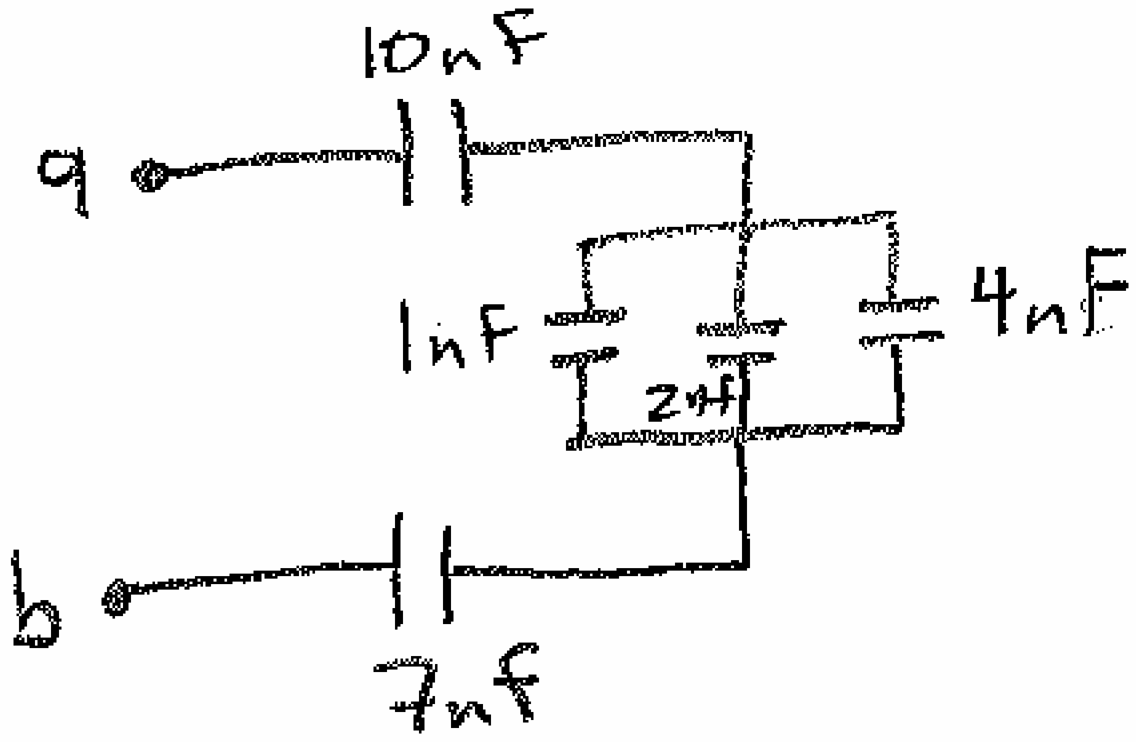
Last time we left of with a promise of an ①

example with many capacitors. As a reminder, last time we found

<u>Parallel</u>  ... $C_{eq} = C_1 + C_2 + C_3$

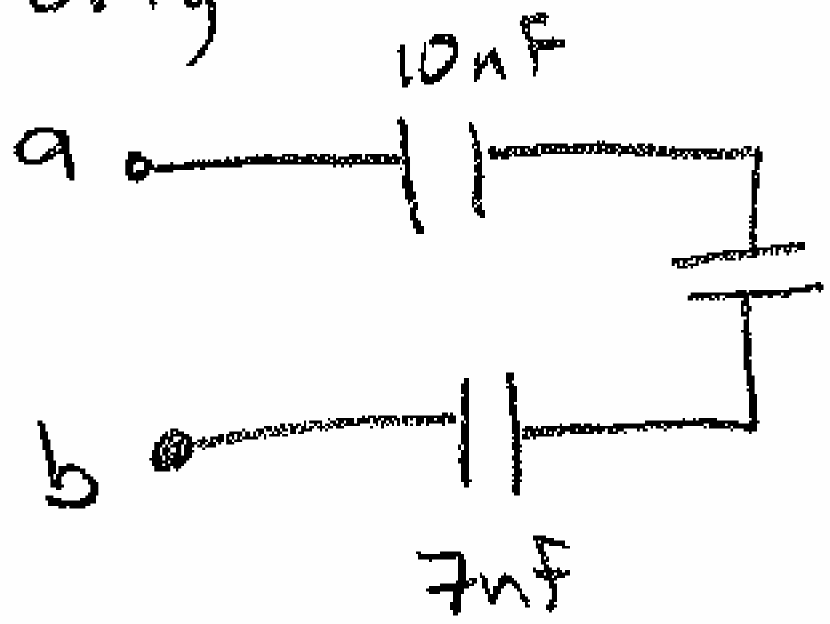
<u>Serial</u>  $\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots$ $Q = CV$, $u = \frac{1}{2}CV^2$

now, consider the following combination of capacitors (we'll hook up a battery between a & b later) what is C_{ab}?



We attack these combos by noting which groups of capacitors can be simplified

<u>Step 1</u> simplify group of 3 in parallel, I.e. we can replace the original circuit with



$7nF = 1nf + 2nf + 4nF = C_{group}$

<u>Step 2</u> note all remaining are in series so $\frac{1}{C_{AB}} = \frac{1}{10nf} + \frac{1}{7nf} + \frac{1}{7nf}$

or $C_{AB} = 2.59nF$

now, suppose we put 5.0V across a-b, what is the charge on the 4nf capacitor? the $Q_{ab} = V_{ab}C_{ab} = (5.0V)(2.59nF) = 12.96nC$ the this Q_{ab} is the same charge as the charge on the 10nF, the combo in parallel and the 7nf capacitor. So, we know ΔV across the 4nF capacitor. $\Delta V_{group} = Q_{ab}/C_{group} = 12.96nC/7nF$

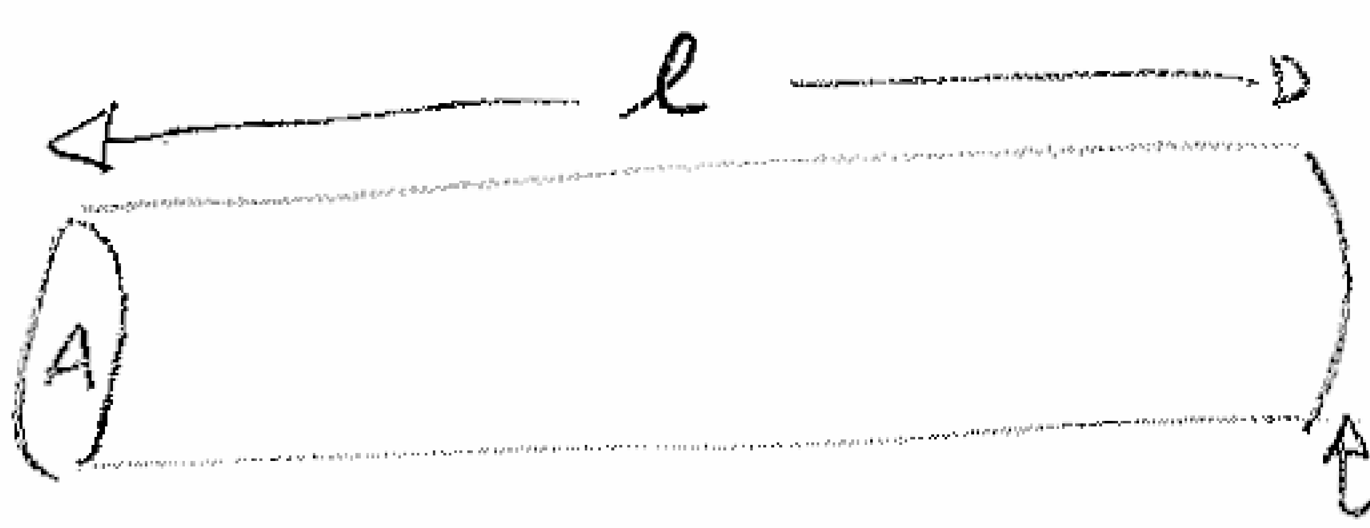
$\Delta V = 1.85V$, so Q on the 4nF capacitor is $(1.85V)(4nf) = 7.4nC$

check! $[(1.85V)(1nF) = 1.85nC] + [1.85V(2nF) = 3.70nC] + 7.4nC = 12.95nC$

All adds up!

So far, we haven't discussed what real conductors might act like. You may have seen or played with or noticed that the flow of charge is measured in C/s or $I = \frac{\Delta Q}{\Delta t}$ in units called amps. & Amps are not unlimited (we have fuses etc.). When we put a ΔV across a wire, the flow of charge has a limiting value, in fact it looks like the I we get can depend on temperature in a conductor. Let's examine current in a ittle detail. In apiece of conductor, there are a number of charges that are free to move around: $n = \frac{\#\text{ free to move}}{\text{Volume}}$ with charge q.

when these charges move in the wire, they tend to bump into other atoms, give up energy, & slow down. Sort of like start & stop traffic. Now, think about a wire full of charge



if the charges in the length ℓ of wire move past this point in time Δt we have

$$\frac{\Delta Q}{\Delta t} = \frac{nA\ell q}{\Delta t}$$

the charge carriers are ccelerating & stopping over & ver again, they'll have some sort of average velocity V_{drift} alled drift velocity

$$\& \quad I = (nAq)\, V_{drift}$$

You can take this further & say that

$$V_{Drift} \sim \underbrace{\frac{qE}{m}}_{\text{acceleration due to an applied e field}} \underbrace{\tau}_{\text{avg time between collisions}}$$

$$I = (nAq)\,\frac{qE}{m}\,\tau$$

& across this length ℓ, the change in electric potential due to $E = E\ell$

$$I = \left[\frac{nAq^2\tau}{m\ell}\right] E\ell$$

your book likes

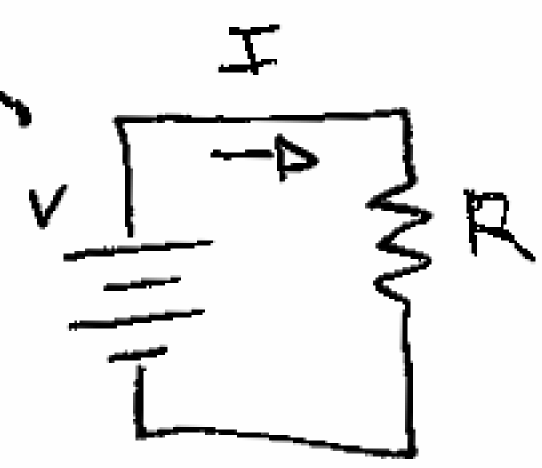
where $\frac{nq^2\tau}{m}$ is called the conductivity

& $\frac{m}{nq^2\tau}$ is called the resistivity (ρ)

$$I = \left(\frac{A}{\rho\ell}\right) \underbrace{E\ell}_{\Delta V}$$

(also means $\rho = E / \underbrace{(I/A)}_{J}$)

& your probable familiar with



resistance

$$\Delta V = IR$$

units of Ohms (Ω) $\quad R = \frac{\rho\ell}{A}$

In the demo, we saw the wire heat up. The amout of power being dissipated $= \frac{(\Delta Q\,\Delta V)}{\Delta t} = I(\Delta V) = I^2R$
$= \frac{V^2}{R}$

& the temperature behavior we saw

$$\rho(t) = \rho_0 [1 + \alpha (T - T_0)]$$

& For lots of materials, ℓ, A don't change much compared to ρ in terms of R so,

$$R(t) = R_0 [1 + \alpha (T - T_0)]$$

in general $\uparrow$ Temp, $\uparrow R$ for conductors.

Example Power in a light bulb
when it's lit, uses 100 W of Power & the Filament reaches a temperature of about 3000°C

question: how much power does it draw @ 20°C if ΔV remains constant when its 1st turned on?

$$\text{Power} = I(\Delta V) = \frac{(\Delta V)^2}{R}$$

$\alpha_{\text{tungsten}} = \frac{0.0045}{°C}$ @ 20°C

$$\text{Power}_{on} = 100\,W = \frac{(\Delta V)^2}{R_{on}}$$

$$\text{Power}_{20°} = \frac{(\Delta V)^2}{R_{20°}}$$

$$\frac{\text{Power}_{on}}{\text{Power}_{20°}} = \frac{(\Delta V)^2 / R_{on}}{(\Delta V)^2 / R_{20°}} = R_{20°} / R_{on}$$

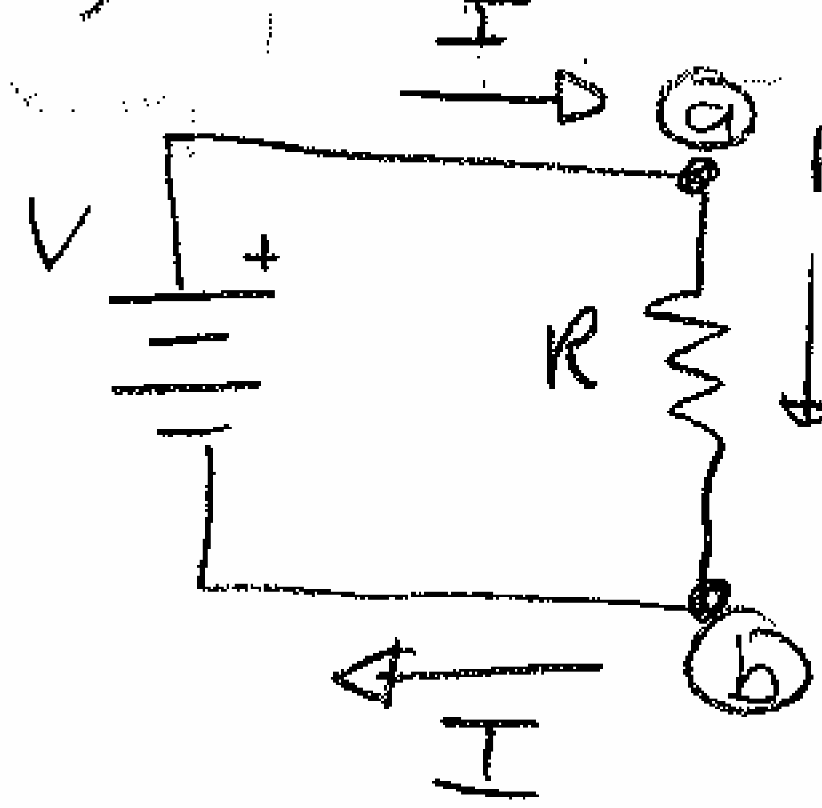
$$\text{or Power } 20° = \text{Power}_{on} \left(\frac{R_{on}}{R_{20°}}\right) = 100\,W \, \frac{R_{20}\left(1 + \frac{0.0045}{°C}(2980°C)\right)}{R_{20}}$$

$$= 1441\,W!$$

when 1st turn on

And if there is an imperfection in the wire, (S) that smaller portion has bigger R (since A shrank) so the bulb can get real hot in one spot.

Notice



point (a) is at a higher electric potential than (b) we have implicitly set up I to be a positive charge flow

positive charges flow from high to low potential which makes I

Expectations

$R = \frac{\rho l}{A}$

$= 2l$

if same material $R \Rightarrow 2R$

$= 2A$

if same material $R \Rightarrow \frac{R}{2}$

$R_{series} = R_1 + R_2 + R_3$

$\frac{1}{R_{parallel}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

notice $Q = CV$

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

Last Example Fuses

Assume takes Power to melt, but blow at a Current

$I^2 R = P \Leftarrow$ determine by experiment

For same material we just want to use a different thickness our stamping machine

$P_{30A} = P_{20A}$

$$\frac{(30A)^2 \rho (\text{length})}{(\text{width} \times \text{thick}_{30A})} = \frac{(20A)^2 \rho (\text{length})}{(\text{width} \times \text{thick}_{20A})}$$

or $\text{thick}_{20A} = \text{thick}_{30A} \left(\frac{20A}{30A}\right)^2_{R \sim \frac{1}{2}}$