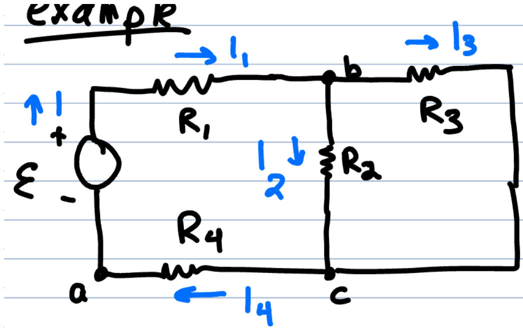
Circuit Lollapalooza

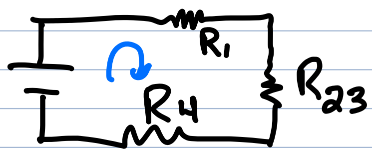
example



"RC" circuit from AI

An easier alternative: realize that R_2 & R_3 are in parallel

$$R_{23} = \frac{R_2 R_3}{R_2 + R_3} = 12\,\Omega$$



$\sum \Delta V = 0$: $\mathcal{E} - I(R_1 + R_{23} + R_4) = 0$

$\longrightarrow I = \frac{\mathcal{E}}{R_1 + R_{23} + R_4} = 0.107\text{ A}$

conceptual follow-up: what should we expect for I if $R_2 \gg R_1, R_3, R_4$

math: $R_{23} = \frac{R_2}{R_2} \frac{R_3}{1 + R_3/R_2} \rightarrow R_3$

inspection: current would ignore $R_2 \rightarrow I = \frac{\mathcal{E}}{R_1 + R_3 + R_4}$

Q: Suppose you want to maximize the lifetime of the battery here, and to do so you may remove one resistor. If $R_1 = R_2 = R_3 = R_4$ which should you remove?

Brute force way:

To maximize the lifetime, minimize power output $P = \frac{\text{energy}}{\text{time}}$

and $P = \mathcal{E}^2 / R_{eq}$ $\Rightarrow$ thus maximize R_{eq}

$R_{eq} = R_1 + R_{23} + R_4 = \frac{5}{2} R$

removing R_1 or R_4 : $R_{eq} = \frac{3}{2} R$

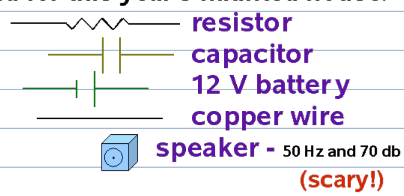
removing R_2 or R_3 : $R_{eq} = \frac{6}{2} R$

} Remove R_2 or R_3

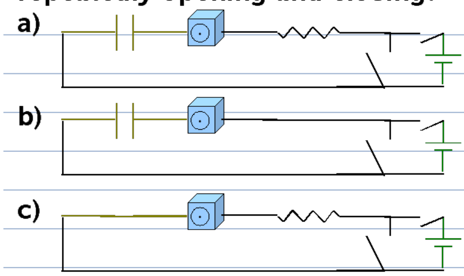
Pondering: resistors in parallel decrease overall R_{eq}, so remove one of them

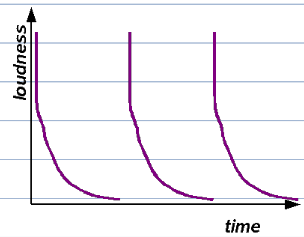
It's 4:00 pm on October 31, and you just realized that it was your job to contribute the scary sound for this year's haunted house.

Supplies at hand:

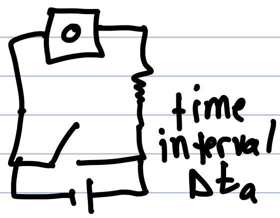


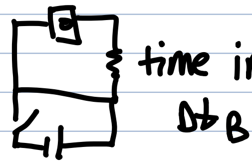
For optimal scariness, you should modulate the sound by repeatedly opening and closing:





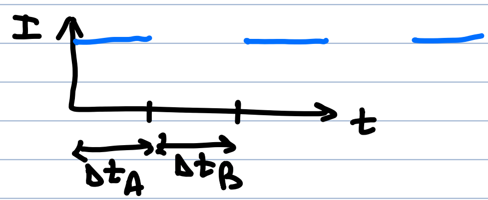
option c

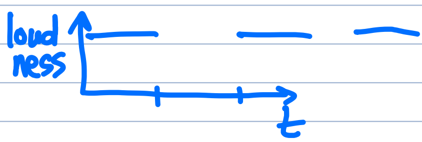




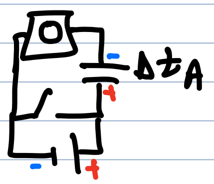
etc

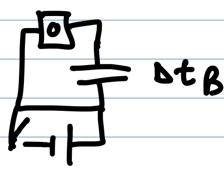
opening and closing switches gives

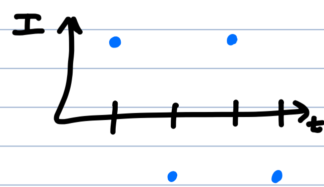




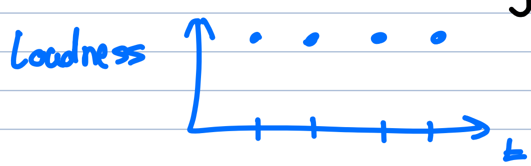
option b



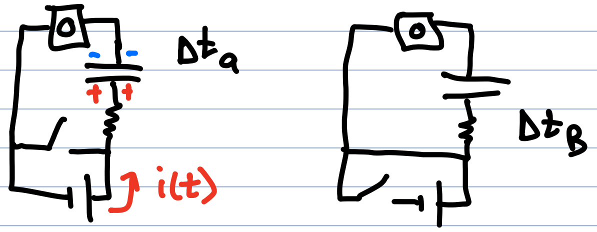




(assume speaker has no r) instantaneous currents, for charging & discharging



option a



in Δt_A, charge builds up on capacitor $V_c(t) = q(t)/c$ $(I \neq 0)$

until at some much later time t_f $V_c(t_f) \simeq \frac{Q_f}{C}$

"loop it" : $\mathcal{E} - i(t)R - \frac{q(t)}{C} = 0$

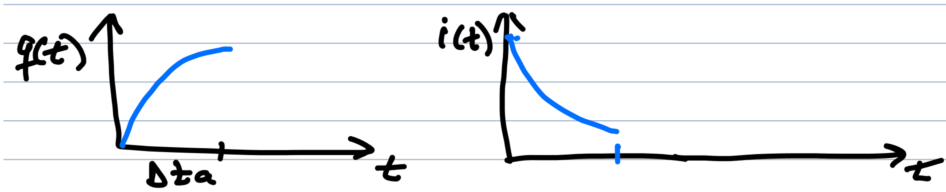
$$i = \frac{dq}{dt} \Rightarrow \mathcal{E} - \frac{dq(t)}{dt} - \frac{q(t)}{C} = 0$$

$$\boxed{q(t) = C\mathcal{E}\left(1 - e^{-t/RC}\right)}$$ charging capacitor in RC circuit

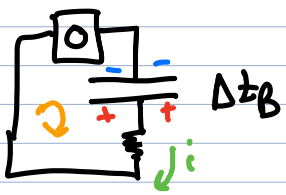
Does this eq^n work? $q(0) = 0$ ✓
$q(t_f \to \infty) = C\mathcal{E}$ ✓

the current is $\frac{dq(t)}{dt} = C\mathcal{E}\left(0 + \frac{1}{RC} e^{-t/RC}\right) = \boxed{\frac{\mathcal{E}}{R} e^{-t/RC}}$

Does this work? $i(0) = \mathcal{E}/R$ ✓
$i(t_f \to \infty) = 0$ ✓



in Δt_B what happens when the battery is removed?
capacitor discharges

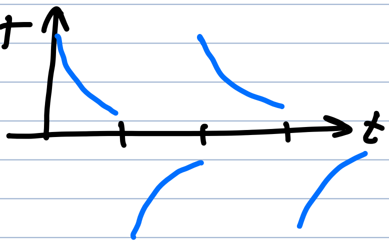


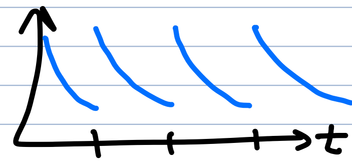
"loop it" $-iR - \frac{q}{C} = 0 \Rightarrow i(t) = \frac{-q(t)}{RC}$

$$\Rightarrow \frac{dq(t)}{dt} = -\frac{q(t)}{RC} \Rightarrow \int_Q^q \frac{dq'}{q'} = \int_0^t \frac{-dt'}{RC}$$

$\ln \frac{q}{Q} = \frac{-t}{RC} \Rightarrow q = Qe^{-t/RC}$

$i = \frac{dq}{dt} = -\frac{Q}{RC} e^{-t/RC}$

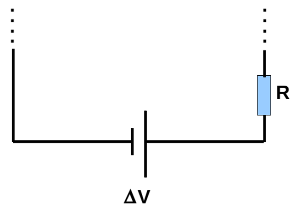




This is a portion of a circuit loop.

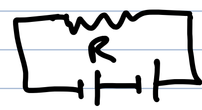
a) Current flows clockwise.
b) Current flows counterclockwise.
c) Current direction depends on the rest of the circuit.

ch 10 Concept Q #4



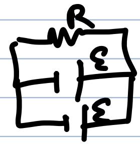
Why are batteries in a flashlight connected in series?

(assume no $r_{internal}$)



$I = \frac{2\mathcal{E}}{R}$

Would there be any advantages to having them in parallel?



$I = \frac{\mathcal{E}}{R}$ half the brightness
⇒ lasts longer

also, still works if one battery dies

concept Q #6 ch10

same ΔV and twice the resistance? $\frac{1}{2}$ the current → 1A

#7 ⓒ light bulb gets short-circuited

#8