(1) Phys 1402 2014-09-23

Total Amount vs. Rate

Charge $\Delta Q = I \, \Delta t$

Energy Energy $= P \, \Delta t$

Power P in watts ($1 \text{ W} = 1 \text{ J/s}$)
Electric power $P = IV$

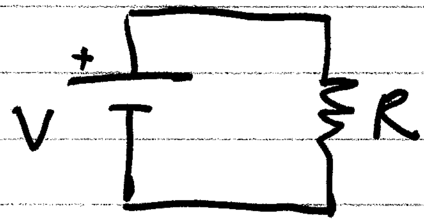
If P in kW and Δt in hours:
Energy in kWh

$P = 100 \text{ W} = 0.1 \text{ kW}$

Ex: A bulb for a month
Energy $= (0.1 \text{ kW})(720 \text{ hours})$
$= 72 \text{ kWh}$

$(72 \text{ kWh}) \cdot (\$0.12/\text{kWh}) = \$8.64$

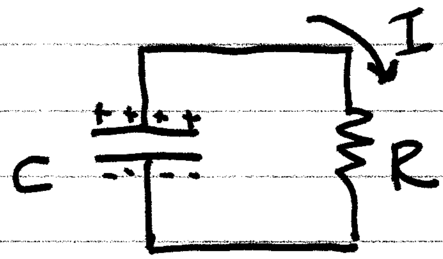
What happens when you hook a battery to a resistor?



Current $I = V/R$ is constant.

What happens if you hook a charged capacitor to a resistor?

$C = \frac{K \varepsilon_0 A}{d}$



$V_c = Q/C$

Current Flows $I = \frac{V_c}{R}$

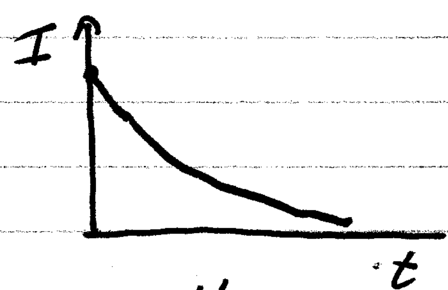
V_{batt} is steady.

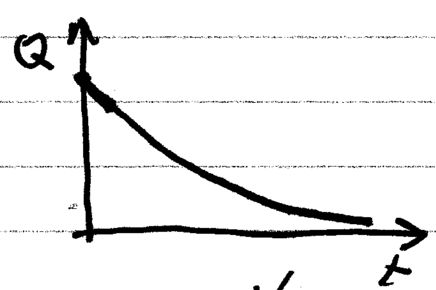
V_c varies depending on Q. ← charge of capacitor

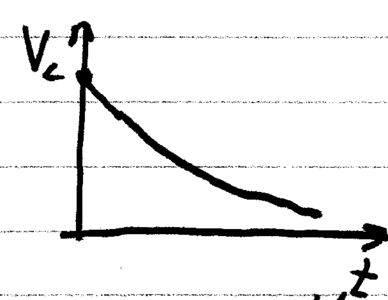
As I flows, Q decreases.

As Q drops, V_c decreases.

As V_c decreases, I decreases.







$I = I_0 e^{-t/\tau}$

$Q = Q_0 e^{-t/\tau} = Q_0 \exp(-t/\tau)$

$V = V_0 e^{-t/\tau}$

③

Ex: $\tau = 5\,s$ $\quad V_o = 100\ V$

$t\ (s)$	$V\ (V) = V_o e^{-t/\tau}$	
0	$V_o e^{-0} = V_o = 100$	} Lost 18 V
1	$(100)e^{-1/5} = (100)(0.82) = 82$	} Lost 15 V
2	$(100)e^{-2/5} = \quad = 67$	
⋮		
$5 = \tau$	$(100)e^{-1} = 100/e = 37$	
⋮	(when $\tau = t$, $V/V_o = 0.37$)	
10	$= 14$	

N.b. $14 = 37\%$ of 37

$$e^{-2} = (e^{-1})(e^{-1}) = (0.37)(0.37)$$

Every τ, V gets cut to 37% of what it was at the last checkpoint.

When does V get cut in half?

$$V = V_o e^{-t/\tau} = V_o(0.5)$$

$$e^{-t/\tau} = 0.5 \qquad \ln() \text{ both sides}$$

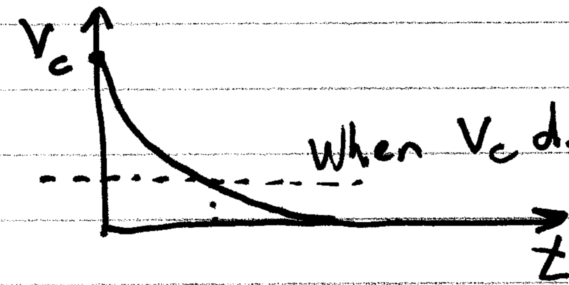
$$-t/\tau = \ln(0.5)$$

$$t = -\tau \ln(0.5) = 0.693\,\tau = \lambda_{1/2}$$

How big is τ? $\tau = RC$

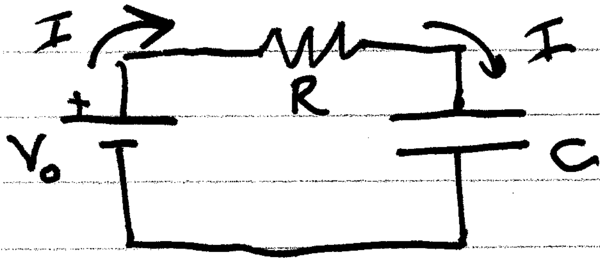
Bigger R drains slower ↗ (R)

Bigger C needs more draining. ↖ (C)



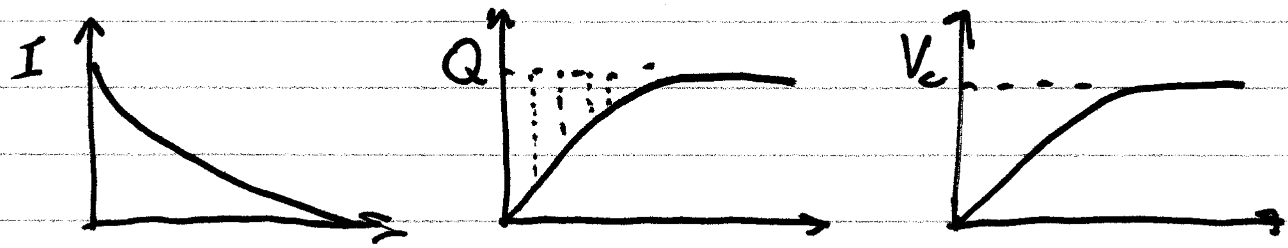
When V_c drops below here, Finished our timing.

How do we charge a capacitor?



$$V_0 = V_R + V_C$$

	Initial	Then...	...Eventually
Q	$Q=0$	Q increases	Q is max
V_C	$V_C=0$	V_C increases	$V_C = V_0$
V_0	V_0	V_0	V_0
V_R	$V_R=V_0$	V_R decreases	$V_R = IR = 0$
I	$I_0 = \frac{V_0}{R}$	I decreases	$I = 0$



$I = I_0 e^{-t/\tau}$ $\quad Q_0 - Q = Q_0 e^{-t/\tau}$ $\quad V_0 - V = V_0 e^{-t/\tau}$

Q exponentially approaches Q_0
V " " V_0

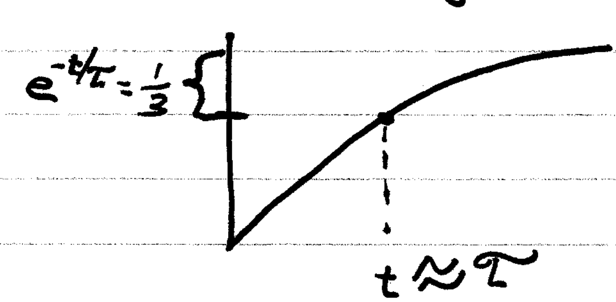
Summary

Current $\qquad I = I_0 e^{-t/\tau}$

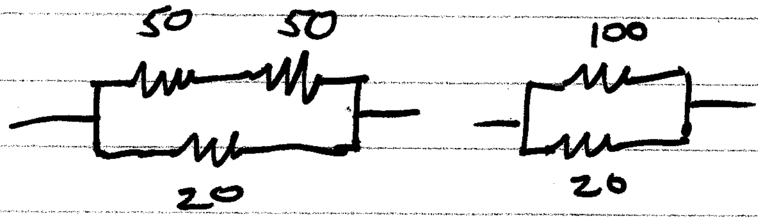
	Discharge	Charge
Voltage	$V = V_0 e^{-t/\tau}$	$V = V_0 \left(1 - e^{-t/\tau}\right)$
	Starts @ V_0	Starts @ 0
	Ends @ 0	Ends @ V_0
	Discharge	Charge

$I_0 = V_0 / R \qquad Q = CV \qquad \tau = RC$

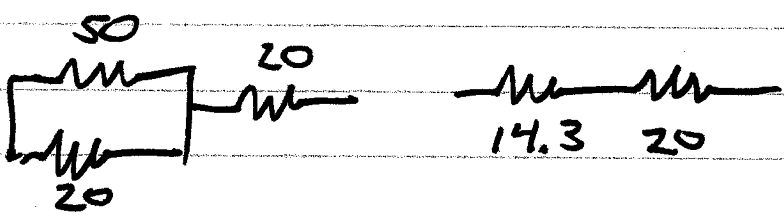
$e^{-t/\tau}$ is the fraction of the process remaining.



Out of 20 Ω and 50 Ω R's, what can you build?



16.7 Ω



34.3 Ω