Chapter 9: Current & Resistance

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Current & Resistance Summary

In this chapter we analyze electrodynamic situations in which charges are moving in a current. Using Ohm's Law, we can analyze the effect of resistance on a circuit's current and potential difference.

Topics to Cover

1. Electric Current
2. Resistance
3. Ohm's Law
4. Electric Energy & Power

Terms and Equations to Know

1. Current:

$$I_{avg} = \frac{\Delta charge}{\Delta time} = \frac{\Delta Q}{\Delta t}, \quad I_{inst} = \frac{dQ}{dt} \qquad [Amperes] = \frac{[Coloumbs]}{[seconds]}$$

2. Ohm's Law:

$$V = (Current)(Resistance) = IR \qquad [Volts] = [Amperes][Ohms]$$

3. Resistance:

$$R = \rho \frac{L}{A} = (\text{material resistivity}) \frac{(length)}{(meters^2)}$$

4. Material Resistivity:

ρ in $R = \rho \frac{L}{A}$, denotes the resistivity of material ie. copper vs. carbon

5. Resistor Code

6. Power "dissipated"

$$P = IV = (current)(voltage) \quad P = \frac{V^2}{R} = \frac{(Voltage)^2}{(Resistance)}, \quad P = I^2R = (Current)^2(Resistance)$$

Ohm's Law

$V = IR$

Voltage[V] = Current[A] · Resistance[Ω]

(means they have a proportional r/t)

$\downarrow$

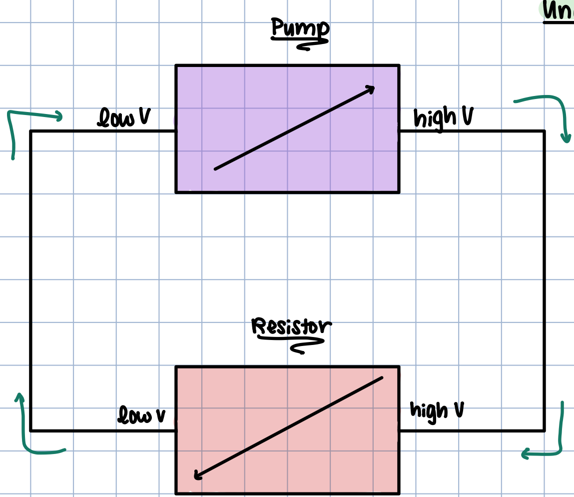
$I \propto V$

only ohmic conductors follow this proportional relationship b/w voltage and current

Resistor Codes

Black - 0	Green - 5
Brown - 1	Blue - 6
Red - 2	Violet - 7
Orange - 3	Gray - 8
Yellow - 4	White - 9

Understanding Current in Action



E is constant everywhere bc flow of current "leaving" equals flow of current "entering"

Understanding Current & Ohm's Law through a Water Hose Analogy

- V Electric Potential = Water Pressure bc dictate flow of e^-
- ρ Resistor = pipe's obstructive objects bc material's individual resistivity for flow
- L Length of System = Length of pipe (connected) bc shorter means easier for flow
- A Cross-Sectional Area = Space water has to flow through (cross-sect. area of pipe)
- I Current = Water flow bc like flow of e^-
- R Resistor = Level of "clog" in the water pipe bc determine inhibition of flow

FRQ #1 → 2016 #2

a) It is the same through both because the resistors are in series.

↳ resistance & current in series vs in parallel

b) It depends on the resistance of the sample since we don't have any information about the magnitudes of these resistances.

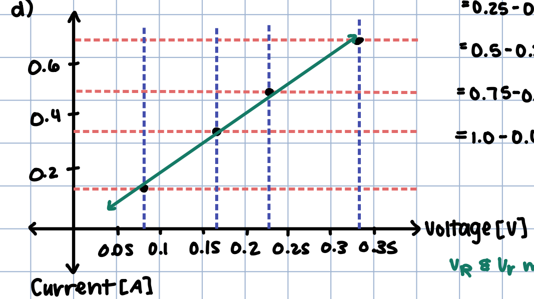
c) Horizontal Axis: Voltage across r   Column Added: V_r (V)

Vertical Axis: Current $R = \frac{V}{I}$ ↳ current is the same, so only need potential difference

better to flip them for solving slope

Ohm's Law: $V = IR$, $V \propto I$ is a relationship of proportionality that's represented through the graph.

d)



$V_r = \varepsilon - V_R$

$= 0.25 - 0.179 = 0.071$

$= 0.5 - 0.335 = 0.165$

$= 0.75 - 0.52 = 0.23$

$= 1.0 - 0.670 = 0.33$

V_R & V_r must add up to ε bc that's when V drops, and $V_{enter} = V_{leave}$

e) $V = IR$, $R = \frac{V}{I} = \frac{\Delta V}{\Delta I} = \frac{0.33 - 0.071}{0.687 - 0.162} = \boxed{0.493\,\Omega}$ → used Ohm's Law to calculate resistance based on the graph

f) $R = \rho \frac{L}{A}$ ← material resistivity

$\rho = \frac{RA}{L} = \frac{(0.493)\pi(1.0 \times 10^{-3})^2}{3.0} = \boxed{5.16 \times 10^{-7}\,\Omega m}$

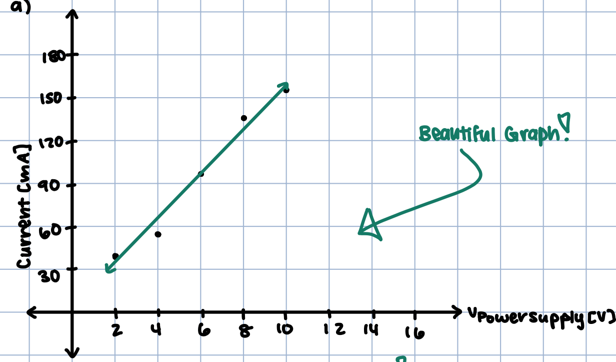
gi) The actual resistance would be ~~less than~~ because the unassumed internal resistance of the battery will increase our known resistance.

gii) The readings of the ammeter would be greater than the actual value because the unideal voltmeter would cause their to be a resistor in parallel. This would decrease the circuits resistance and increase the current, causing a higher read on the ammeter than before.

↳ ideal vs. unideal ammeters & voltmeters

FRQ #2 → 2014 #1

a)

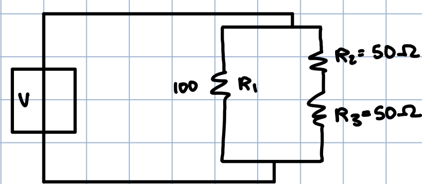


Beautiful Graph!

b) $R_T = \frac{10 - 2}{(155 - 40) \times 10^{-3}} = \boxed{69.57\,\Omega}$

Ohm's Law! $V = IR$, so $R = \frac{V}{I} = \frac{\Delta V}{\Delta I}$

c) R_1 = ??



calculating total resistance in parallel:

$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2 + R_3}$

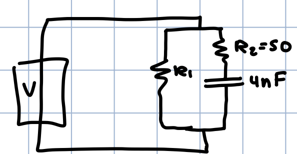
$\frac{1}{69.57} - \frac{1}{100} = \frac{1}{R_1}$

$\boxed{R_1 = 228\,\Omega}$

d) $I = \frac{V}{R_1} = \frac{12V}{100\Omega} = \boxed{0.12A}$

potential across is the same bc in parallel, current can differ in parallel

ei)



Ohm's Law! $V_{batt} = V_{R_1} = V_{R_2}$

$I = \frac{V}{R} = \frac{12V}{50\Omega} = \boxed{0.24A}$

eii) The magnitude of the current would be ~~less than~~ part d because the capacitor would have charged up, causing push back and making $I = 0$ across R_2.

↳ making $V_C = \varepsilon$, so no ΔV when charges cross over it

f) It would be equal to ei because an uncharged capacitor wouldn't affect the current immediately after in either case.

FRQ #3 → 2019 Set 1 #2

a) i. $I_1 + I_3 = I_2$

$150 I_1 + 200 I_2 = 6.0$

$100 I_3 + 200 I_2 = 6.0$

Using Kierkeuff's Loop & Node Rules!

ii. $I_1 + 1.33 I_2 = 0.04$

$\cancel{I_3} + 2I_2 = 0.06$

$+ \; I_2 - \cancel{I_3} + 1.33 I_2 = 0.04$

$2I_2 + 3.33 I_2 = 0.1$

$4.33 I_2 = 0.1$

$\boxed{I_2 = 0.023 A}$

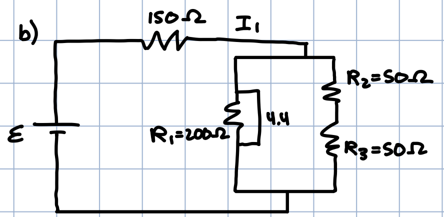
substitue to isolate I_2

equation for power dissipated

iii. $P = I^2 R = (0.023 A)^2 (200 \Omega) = \boxed{0.107 W}$

↪ can use Ohm's Law ($V = IR$) for different solutions

b)



$I = \frac{V}{R} = \frac{4.4}{150} = \boxed{0.029 A}$

→ solve for current & resistance to get potential

c) $\varepsilon = I_1 R_T$ Ohm's Rule!

$I_1 = I_2 + I_3$

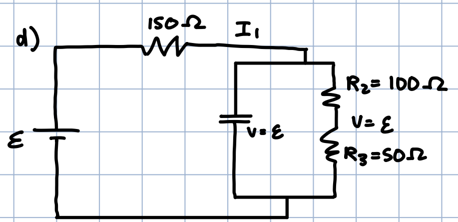
$I_2 = 0.023 + 0.029$

$= 0.052$

$R_T = \underbrace{150 + \underbrace{\frac{1}{\left(\frac{1}{200} + \frac{1}{150}\right)}}_{R_{parallel}}}_{R_{series}} = 235.7\Omega$

$\varepsilon = (0.052 A)(235.7\Omega) = \boxed{12.3V}$

d)



$I = \frac{V}{R} = \frac{12.3}{150 + 150}$

$= \boxed{0.041 A}$

↪ upon reaching a steady state, $V_c = \varepsilon$, so V on right = ε. Also, capacitor is fully charged! Push back causes all current to pass through right, which is why right is now in series w/ ε!

ii. The current is <u>less than</u> bc the inductor at steady state is like a short-circuit since $dI/dt = 0$. Thus, no current will take the right side.

FRQ #5 → 2007 #1

a) $\varepsilon = I_{max} R = (2.25 \times 10^{-3} A)(550\Omega) = \boxed{1.238 V}$

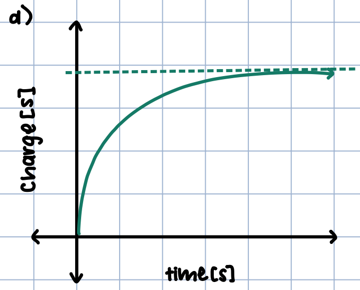
b) $V = V_0 (1 - e^{-t/RC}) = 1.238(1 - e^{-4/(550 \times 4000 \times 10^{-6})}) = \boxed{1.037V}$

c) $Q = Q_{max}(1 - e^{-t/RC}) = (4000 \times 10^{-6})(1.037)(1 - e^{-4/(550 \times 4000 \times 10^{-6})})$

$= \boxed{3.47 \times 10^{-3} C}$

↪ or even: $I = \frac{dQ}{dt} \rightarrow Q = \int I dt$

d)



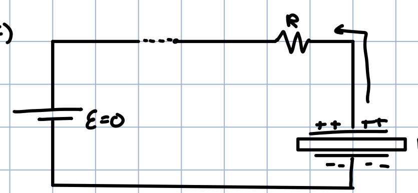
e) $P_R = \frac{V^2}{R}$, @ t = 0

$V_R = \varepsilon - V_c = (1.238) - (1.037)$

$= 0.201$

$P_R = \frac{(0.201)^2}{550} = \boxed{7.35 \times 10^{-5} W}$

f)

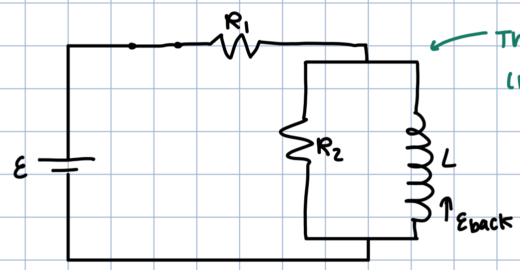


↪ Capacitance Increases

· The charge left on these plates during discharge is greater than the charge during charging at t = 4s. Since there is a dialectric, the capacitance has increased, so the max Q has increased.

$Q = CV_0(e^{-t/RC})$

$\boxed{\text{FRQ \#4}} \rightarrow$ 2005 #2



This is an RL circuit (Resistance + Inductor)

Ohm's Law!

a) $I = \frac{\mathcal{E}}{R_T}$ $\quad R_T = R_1 + \frac{1}{1/R_2} = R_1 + R_2$ → bc inductor has no resistance, so basically in series

$\boxed{I = \frac{\mathcal{E}}{R_1+R_2}}$

Change in current & Inductance affect the voltage across an inductor

b) $\mathcal{E} = -L\frac{dI}{dt}$

$\mathcal{E} = IR_2$

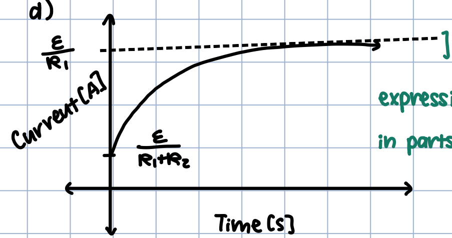
$I = \frac{\mathcal{E}}{R_1+R_2}$

$\boxed{\frac{\mathcal{E}R_2}{L(R_1+R_2)} = \frac{dI}{dt}}$

c) $I = \frac{V}{R} = \boxed{\frac{\mathcal{E}}{R_1}}$ → not R_T because reach steady state after a long time. Current isn't changing, so $L = 0$ & $V_L = 0$. R_2 is short-circuited! → $V_{batt} = V_{R_2}$

→ don't need to know for resistance & current chapter, but this question uses Ohm's Law, which you should know!

d)

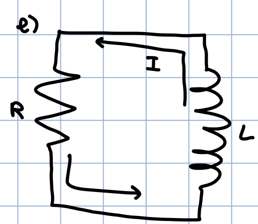


]approaching max-value

expressions were solved for in parts a & c

→ Inductor fights changing current with a back ε that, ultimately, causes the current to reach a steady-state

e)



$I_{R_2} = I_L, \quad I_L = I_{batt}$

$\frac{V_{R_2}}{R_2} = \frac{\mathcal{E}}{R_1}$

$\boxed{V_{R_2} = \frac{\mathcal{E}R_2}{R_1}}$

substitute, substitute, substitute!