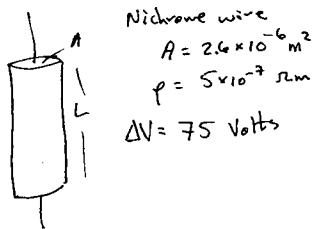


26.47



$$\text{a) Power} = IV \xrightarrow{V=IR} \frac{V^2}{R}$$

$$5000 \text{ Watts} = \frac{75^2}{R}$$

$$R = 1.125 \Omega$$

then

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

$$1.125 = (5 \times 10^{-7}) \frac{L}{2.6 \times 10^{-6}}$$

$$L = 5.85 \text{ meters}$$

$$\text{b) Repeat with } \Delta V = 100 \text{ Volts}$$

$$\text{Power} = IV \xrightarrow{V=IR} \frac{(100)^2}{R}$$

$$5000 = \frac{(100)^2}{R}$$

$$R = 0.5 \Omega$$

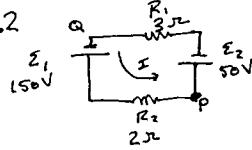
then

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

$$0.5 = (5 \times 10^{-7}) \frac{L}{2.6 \times 10^{-6}}$$

$$L = 2.6 \text{ meters}$$

27.2



First figure out the current in the circuit.
 start at Q and go CCW

$$E_1 - IR_2 - E_2 - IR_1 = 0$$

$$150 - I \cdot 2 - 50 - I \cdot 3 = 0$$

$$100 - IS = 0$$

$$I = 20 \text{ Amps}$$

Now to answer the question.

we start at P with 100 Volts

we climb backwards through the resistor $-(I)R_2$
 we go across the battery the wrong way -150

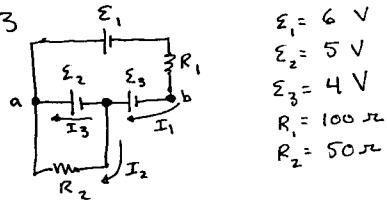
so

$$100 + IR_2 - 150$$

$$100 + 20(2) - 150$$

$$-10 \text{ Volts}$$

27.23



$$\begin{aligned} E_1 &= 6 \text{ V} \\ E_2 &= 5 \text{ V} \\ E_3 &= 4 \text{ V} \\ R_1 &= 100 \Omega \\ R_2 &= 50 \Omega \end{aligned}$$

$$I_1 = I_2 + I_3$$

start SE corner, do upper loop, CW

$$E_3 + E_2 - E_1 - I_1 R_1 = 0$$

start at middle junction, go CW around bottom loop

$$-I_2 R_2 - E_2 = 0$$

Now rewrite equations with values

$$I_1 = I_2 + I_3$$

$$4 + 5 - 6 - I_1 \cdot 100 = 0$$

$$-I_2 \cdot 50 \rightarrow 5 = 0$$

These can be re-written

$$I_1 = I_2 + I_3$$

$$-3 - I_1 \cdot 100 = 0 \rightarrow I_1 = -3/100$$

$$-I_2 \cdot 50 - 5 = 0 \rightarrow I_2 = -1/10$$

then

$$I_1 = I_2 + I_3$$

$$-\frac{3}{100} = -\frac{1}{10} + I_3$$

$$\frac{1}{10} - \frac{3}{100} = I_3$$

$$\frac{10-3}{100} = I_3$$

Summarizing:

$$I_1 = -\frac{3}{100} \quad I_2 = -\frac{1}{10} \quad I_3 = \frac{7}{100}$$

Then to get the potential difference between a,b.

Suppose we start at b with V_b

get boosted by E_3

get boosted by E_2

Arrive at a with V_a

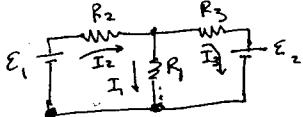
$$V_b + E_3 + E_2 = V_a$$

$$E_3 + E_2 = V_a - V_b$$

$$4 + 5 = V_a - V_b$$

$$9 = V_a - V_b$$

27.36



$$\begin{aligned}\Sigma_1 &= 6 \\ \Sigma_2 &= 12 \\ R_1 &= 100 \Omega \\ R_2 &= 200 \Omega \\ R_3 &= 300 \Omega\end{aligned}$$

$$I_2 = I_1 + I_3$$

start SW corner, go CW around left loop

$$\Sigma_1 - I_2 R_2 - I_1 R_1 = 0$$

start middle-bottom, go CW around right loop

$$-(-I_1) R_1 - I_3 R_3 - \Sigma_2 = 0$$

Now rewrite, filling in the values

$$\textcircled{1} \quad I_2 = I_1 + I_3$$

$$\textcircled{2} \quad 6 - I_2 200 - I_1 100 = 0$$

$$\textcircled{3} \quad + I_1 100 - I_3 300 - 12 = 0$$

Eliminate I_2 in $\textcircled{2}$ using $\textcircled{3}$

$$\textcircled{1} \quad I_2 = I_1 + I_3$$

$$\textcircled{2}' \quad 6 - (I_1 + I_3) 200 - I_1 100 = 0$$

$$6 - I_1 300 - I_3 200 = 0$$

$$\textcircled{3}' \quad I_1 100 - I_3 300 - 12 = 0$$

Solve $\textcircled{3}'$ for I_1 and then plug in $\textcircled{2}'$

$$I_1 100 - I_3 300 - 12 = 0$$

$$I_1 100 = 12 + I_3 300$$

$$I_1 = \frac{12 + I_3 300}{100}$$

$$\textcircled{2}: \quad 6 - I_1 300 - I_3 200 = 0$$

$$6 - \left[\frac{12 + I_3 300}{100} \right] 300 - I_3 200 = 0$$

$$6 - 36 - I_3 900 - I_3 200 = 0$$

$$-30 - I_3 1100 = 0$$

$$-I_3 1100 = 30$$

$$I_3 = -\frac{30}{1100} = -0.02727 \text{ Amp}$$

Then to get I_1

$$I_1 = \frac{12 + I_3 300}{100} = \frac{12 + -\frac{30}{1100} 300}{100}$$

$$= 0.03818 \text{ Amp}$$

Then to get I_2

$$\begin{aligned}I_2 &= I_1 + I_3 = 0.03818 + -0.02727 \\ &= 0.01091 \text{ Amp}\end{aligned}$$



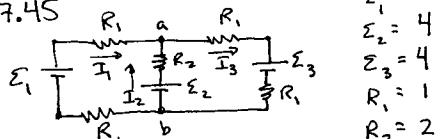
If the bottom of the circuit is zero volts must climb through R_3 to get to a .

$$0 - (-I_3) R_3 = V_a$$

$$0.03818 (300) = V_a$$

$$3.818 \text{ Volts} = V_a$$

27.45



$$\begin{aligned}\Sigma_1 &= 2 \\ \Sigma_2 &= 4 \\ \Sigma_3 &= 4 \\ R_1 &= 1 \\ R_2 &= 2\end{aligned}$$

$$I_1 + I_2 = I_3$$

start SW corner, go CW around left loop

$$\Sigma_1 - I_1 R_1 - (-I_2) R_2 - \Sigma_2 - I_3 R_1 = 0$$

start middle-bottom, go CW around right loop

$$\Sigma_2 - I_2 R_2 - I_3 R_1 - \Sigma_3 - I_3 R_1 = 0$$

Rewrite, filling in numbers

$$\textcircled{1} \quad I_1 + I_2 = I_3$$

$$2 - I_1 1 + I_2 2 - 4 - I_3 1 = 0$$

$$4 - I_2 2 - I_3 1 - 4 - I_3 1 = 0$$

Simplify

$$\textcircled{1} \quad I_1 + I_2 = I_3$$

$$\textcircled{2} \quad -2 - 2 I_1 + 2 I_2 = 0$$

$$-2 I_2 - I_3 - I_3 = 0$$

$$-2 I_2 - 2 I_3 = 0$$

$$\textcircled{3} \quad I_2 + I_3 = 0$$

Simplify

$$\textcircled{1}' \quad I_1 + I_2 = I_3$$

$$\textcircled{2}' \quad -1 - I_1 + I_2 = 0$$

$$\textcircled{3}' \quad I_2 + I_3 = 0$$

Substitute $\textcircled{3}'$ into $\textcircled{1}'$

$$I_3 = -I_2$$

$$I_1 + I_2 = I_3$$

$$I_1 + I_2 = -I_2$$

$$I_1 + 2 I_2 = 0$$

$$I_1 = -2 I_2$$

plug this into $\textcircled{2}'$

$$-1 - I_1 + I_2 = 0$$

$$-1 - (-2 I_2) + I_2 = 0$$

$$-1 + 2 I_2 + I_2 = 0$$

$$-1 + 3 I_2 = 0$$

$$I_2 = \frac{1}{3}$$

then

$$\begin{aligned}I_1 &= -2 I_2 = -2 \left(\frac{1}{3} \right) \\ &= -\frac{2}{3}\end{aligned}$$

then

$$I_1 + I_2 = I_3$$

$$-\frac{2}{3} + \frac{1}{3} = I_3$$

$$I_3 = -\frac{1}{3}$$

Potential Difference

Start at b with V_b

Cross Σ_2

go through R_2 $-I_2 R_2$

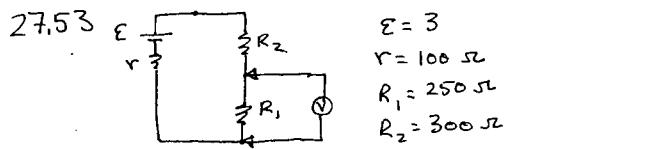
arrive at a with V_a

so $V_b + \Sigma_2 - I_2 R_2 = V_a$

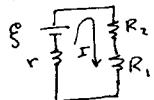
$$\Sigma_2 - I_2 R_2 = V_a - V_b$$

$$4 - \frac{1}{3}(2) = V_a - V_b$$

$$\frac{10}{3} = V_a - V_b$$



Ideally, the circuit is



The current can be calculated as

$$E = Ir + IR_2 + IR_1 = 0$$

$$I = \frac{E}{r+R_2+R_1} = \frac{3}{100+300+250}$$

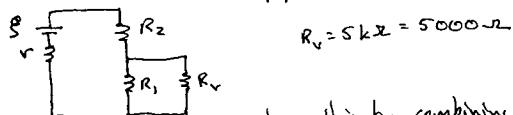
$$= 4.615 \text{ mA}$$

And the potential difference across R_1 is

$$IR_1 = (4.615 \text{ mA}) 250 \Omega$$

$$= 1.15 \text{ Volts}$$

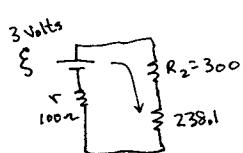
If the voltmeter is cheap, it will load the circuit



Analyze this by combining resistors:

$$\frac{1}{R_{\text{eff}}} = \frac{1}{R_1} + \frac{1}{R_v} = \frac{1}{250} + \frac{1}{5000}$$

$$R_{\text{eff}} = 238.1 \Omega$$

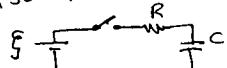


The current is then

$$I = \frac{3}{100+300+238.1}$$

$$= 4.701 \text{ mA}$$

27.58 RC Circuit



$$E = 12 \text{ Volts}$$

$$R = 1.4 \text{ M}\Omega = 1.4 \times 10^6 \Omega$$

$$C = 1.8 \mu\text{F} = 1.8 \times 10^{-6} \text{ F}$$

a) time constant

$$\tau = RC = (1.4 \times 10^6)(1.8 \times 10^{-6})$$

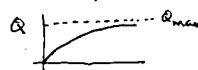
$$= 2.52 \text{ sec}$$

b) Max Charge on Capacitor.

The voltage on the capacitor will build up to 12 Volts

$$Q_{\text{max}} = CV_{\text{max}} = (1.8 \times 10^{-6})(12) = 2.16 \times 10^{-5} \text{ Coulombs}$$

c) How long until $Q = 16 \mu\text{C}$?



$$Q(t) = Q_{\text{max}} [1 - e^{-t/\tau}]$$

$$16 \times 10^{-6} = 21.6 \times 10^{-6} [1 - e^{-t/2.52}]$$

take ln()

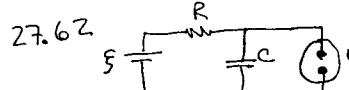
$$0.259 = e^{-t/2.52}$$

$$-1.35 = -t/2.52$$

$$1.35 = t/2.52$$

$$t = 3.40 \text{ sec}$$

27.62

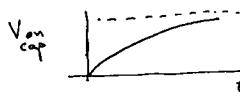


breakdown 72 V

$$E = 95 \text{ V}$$

$$R = ?$$

$$C = 0.150 \mu\text{F}$$



$$V_{\text{on cap}}(t) = E [1 - e^{-t/RC}]$$

$$72 = 95 [1 - e^{-t/RC}]$$

$$0.242 = e^{-t/RC}$$

take ln()

$$1.418 = \frac{t}{RC}$$

$$1.418 = \frac{0.5}{R(0.150 \times 10^{-6})}$$

$$R = 2.35 \times 10^6 \Omega$$

$$= 2.35 \text{ M}\Omega$$

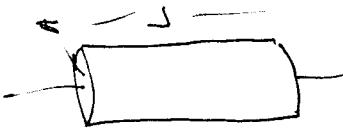
26.47

Nichrome wire

$$A = 2.6 \times 10^{-6} \text{ m}^2$$

$$\rho = 5 \times 10^{-7} \text{ ohm m}$$

$$\Delta V = 75 \text{ Volts}$$



a) Power = $I V = \frac{V^2}{R}$

$$5000 \text{ Watts} = \frac{75^2}{R}$$

$$R = 1.125 \Omega$$

then $R = \rho \frac{L}{A}$

$$1.125 = (5 \times 10^{-7}) \frac{L}{2.6 \times 10^{-6}}$$

$$L = 5.85 \text{ meters}$$

b) Repeat with $\Delta V = 100 \text{ Volts}$
Power = $I V \Rightarrow I = \frac{V}{R}$

$$5000 = \frac{100^2}{R}$$

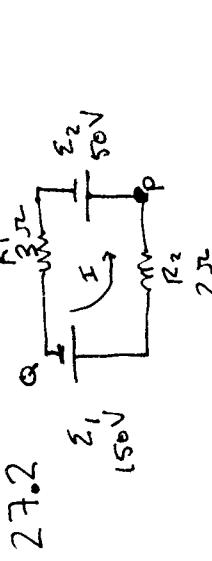
$$R = 0.5 \Omega$$

then

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

$$0.5 = (5 \times 10^{-7}) \frac{L}{2.6 \times 10^{-6}}$$

$$L = 2.6 \text{ meters}$$



27.2

First figure out the current in the circuit.
start at Q and go CCW

$$E_1 - IR_2 - E_2 - IR_1 = 0$$

$$150 - I 2 - 50 - I 3 = 0$$

$$100 - IS = 0$$

$$I = 20 \text{ Amps}$$

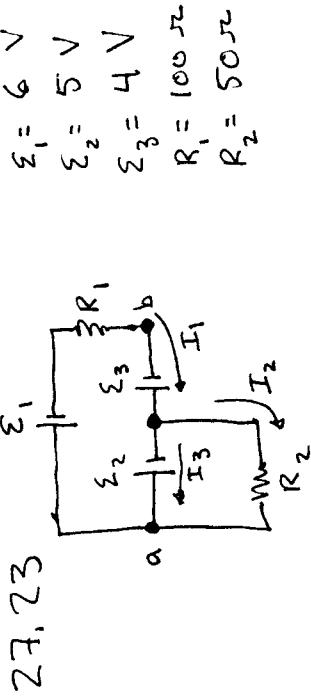
Now to answer the question.

we start at P with 100 Volts
we climb backwards through the resistor $-IR_2$
we go across the battery the wrong way -150
we go ΔV across the resistor -100

$$So \quad 100 + IR_2 - 150$$

$$100 + 20(2) - 150$$

$$-10 \text{ Volts}$$



Summarizing

$$\begin{aligned} \mathcal{E}_1 &= 6 \text{ V} \\ \mathcal{E}_2 &= 5 \text{ V} \\ \mathcal{E}_3 &= 4 \text{ V} \\ R_1 &= 100 \Omega \\ R_2 &= 50 \Omega \end{aligned}$$

$$I_1 = I_2 + I_3$$

start SE corner, do upper loop, CW

$$\mathcal{E}_3 + \mathcal{E}_2 - \mathcal{E}_1 - I_1 R_1 = 0$$

start at middle junction, go CW around bottom loop

$$-I_2 R_2 - \mathcal{E}_2 = 0$$

Now rewrite equations with values

$$I_1 = I_2 + I_3$$

$$4 + 5 - 6 - I_1 / 100 = 0$$

$$-I_2 / 50 - 5 = 0$$

These can be re-written

$$\begin{aligned} I_1 &= I_2 + I_3 \\ -\frac{3}{100} &= -\frac{1}{10} + I_3 \\ -3 - I_1 / 100 &= 0 \rightarrow I_1 = -3/100 \\ -I_2 / 50 - 5 &= 0 \rightarrow I_2 = -1/10 \end{aligned}$$

Then

$$\begin{aligned} I_1 &= I_2 + I_3 \\ -\frac{3}{100} &= -\frac{1}{10} + I_3 \\ \frac{1}{10} - \frac{3}{100} &= I_3 \quad \rightarrow I_3 = \frac{7}{100} \\ \frac{10-3}{100} &= I_3 \end{aligned}$$

Then to get the potential difference between a & b.

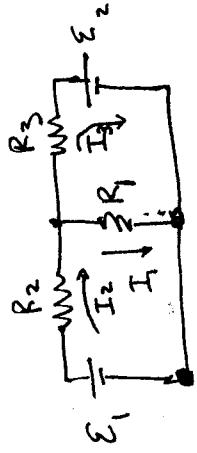
Suppose we start at b with V_b

get boosted by \mathcal{E}_3
get boosted by \mathcal{E}_2
Arrive at a with V_a

$$\begin{aligned} V_b + \mathcal{E}_3 + \mathcal{E}_2 &= V_a \\ \mathcal{E}_3 + \mathcal{E}_2 &= V_a - V_b \\ 4 + 5 &= V_a - V_b \\ 9 &= V_a - V_b \end{aligned}$$

$$q = V_a - V_b$$

27.36



$$\begin{aligned} \Sigma_1 &= 6 \\ \Sigma_2 &= 12 \\ R_1 &= 100 \Omega \\ R_2 &= 200 \Omega \\ R_3 &= 300 \Omega \end{aligned}$$

$$\boxed{\text{I}_2 = I_1 + I_3}$$

start SW corner, go CW around left loop

$$\boxed{\text{I}_1 - \text{I}_2 R_2 - \text{I}_1 R_1 = 0}$$

start middle-bottom, go CW around right loop

$$-(\text{I}_1) R_1 - \text{I}_3 R_3 - \Sigma_2 = 0$$

Now rewrite, filling out the values

$$\boxed{\text{I}_2 = \text{I}_1 + \text{I}_3}$$

$$6 - \text{I}_2 200 - \text{I}_1 100 = 0$$

$$\boxed{\text{I}_1 100 - \text{I}_3 300 - 12 = 0}$$

Eliminate I_2 in $\boxed{2}$ using $\boxed{1}$

$$\boxed{\text{I}_2 = \text{I}_1 + \text{I}_3}$$

$$(6 - (\text{I}_1 + \text{I}_3) 200 - \text{I}_1 100 = 0)$$

$$6 - \text{I}_1 300 - \text{I}_3 200 = 0$$

$$\boxed{\text{I}_1 100 - \text{I}_3 300 - 12 = 0}$$

Solve $\boxed{3}$ for I_1 and then plug in $\boxed{1}$

$$\text{I}_1 100 - \text{I}_3 300 - 12 = 0$$

$$\text{I}_1 = \frac{12 + \text{I}_3 300}{100}$$

$$\boxed{\text{I}_2' : 6 - \text{I}_1 300 - \text{I}_3 200 = 0}$$

$$6 - \left[\frac{12 + \text{I}_3 300}{100} \right] 300 - \text{I}_3 200 = 0$$

$$6 - 36 - \text{I}_3 900 - \text{I}_3 200 = 0$$

$$-30 - \text{I}_3 1100 = 0$$

$$-\text{I}_3 1100 = 30$$

$$\text{I}_3 = \frac{-30}{1100} = -0.02727 \text{ Amp}$$

$$\text{I}_1 = \frac{12 + \text{I}_3 300}{100} = \frac{12 + -\frac{30}{1100} 300}{100}$$

$$= 0.03818 \text{ Amp}$$

Then to get I_2

$$\text{I}_2 = \text{I}_1 + \text{I}_3 = 0.03818 + -0.02727$$

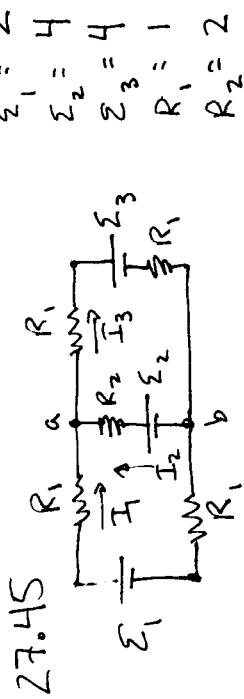
$\text{I}_2 = 0.01091 \text{ Amp}$

If the bottom of the circuit is zero volts
must climb through R_1 to get to a .

$$0 - (-\text{I}_1) R_1 = V_a$$

$$0.03818 (100) = V_a$$

$$3.818 \text{ Volts} = V_a$$



$$\begin{aligned}E_1 &= 2 \\E_2 &= 4 \\E_3 &= 4 \\R_1 &= 1 \\R_2 &= 2\end{aligned}$$

$$I_1 + I_2 = I_3$$

start SW corner, go cw around left loop.

$$E_1 - I_1 R_1 - (-I_2) R_2 - E_2 - I_1 R_1 = 0$$

start middle bottom, go cw around right loop

$$E_2 - I_2 R_2 - I_3 R_1 - E_3 - I_3 R_1 = 0$$

Rewrite, filling in numbers

$$I_1 + I_2 = I_3$$

$$2 - I_1 1 + I_2 2 - 4 - I_1 1 = 0$$

$$4 - I_2 2 - I_3 1 - 4 - I_3 1 = 0$$

Simplify

$$I_1 + I_2 = I_3$$

$$[2] \quad -2 - 2 I_1 + 2 I_2 = 0$$

$$-2 I_2 - I_3 - I_3 = 0 \quad \rightarrow$$

$$-2 I_2 - 2 I_3 = 0 \quad \rightarrow$$

$$I_2 + I_3 = 0 \quad \leftarrow$$

$$[3] \quad \boxed{I_2 + I_3 = 0}$$

Simplify

$$I_1 + I_2 = I_3$$

$$-1 - I_1 + I_2 = 0$$

$$I_2 + I_3 = 0$$

$$\begin{aligned}\text{Substitute } [3] \text{ into } [1] \\ I_3 = -I_2 \\ I_1 + I_2 = I_3 \\ I_1 + I_2 = -I_2 \\ I_1 = -2 I_2\end{aligned}$$

$$I_1 + I_2 = I_3$$

$$-1 - I_1 + I_2 = 0$$

$$-1 - (-2 I_2) + I_2 = 0$$

$$-1 + 2 I_2 + I_2 = 0$$

$$-1 + 3 I_2 = 0$$

$$I_2 = 1/3$$

$$\text{Plug this into } [2]' \\ I_1 = -2 I_2 = -2(1/3)$$

then

$$\begin{aligned}I_1 + I_2 &= I_3 \\-2/3 + 1/3 &= I_3 \\I_3 &= -1/3\end{aligned}$$

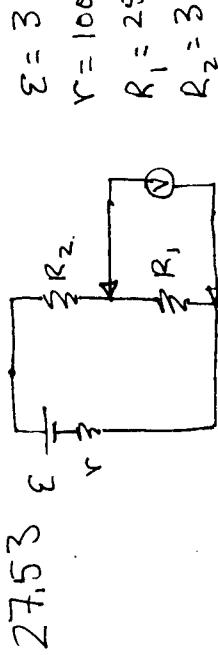
Potential Difference

Start at b with V_b

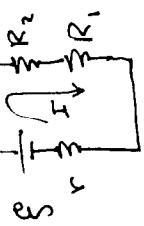
Cross Σ_2 go through R_2 arrive at a with V_a

$$\begin{aligned}\text{So } V_b + \Sigma_2 - I_2 R_2 &= V_a \\ \Sigma_2 - I_2 R_2 &= V_a - V_b \\ 4 - 1/3(2) &= V_a - V_b\end{aligned}$$

$$\frac{10}{3} = V_a - V_b$$



Ideally, the circuit is



The current can be calculated

$$I = \frac{E - Ir - IR_2 - IR_1}{r + R_2 + R_1}$$

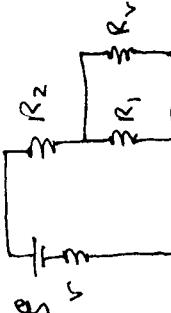
$$I = \frac{3 - 1.15 - 4.615 \times 0.25 - 4.615 \times 0.3}{0.1 + 0.25 + 0.3} = 4.615 \text{ mA}$$

And the potential difference across R_1 is

$$IR_1 = (4.615 \text{ mA}) 250 \Omega$$

$$= 1.15 \text{ Volts}$$

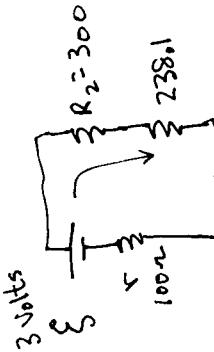
If the voltmeter is cheap, it will load the circuit



Analyze this by combining resistors

$$\frac{1}{R_{\text{eff}}} = \frac{1}{R_1} + \frac{1}{R_v} = \frac{1}{250} + \frac{1}{5000}$$

$$R_{\text{eff}} = 238.1 \Omega$$



$$I = \frac{3}{100 + 300 + 238.1} = 4.701 \text{ mA}$$

The pot'l difference across the 238.1 Ω
resistance is
 $(4.701 \text{ mA})(238.1 \Omega)$

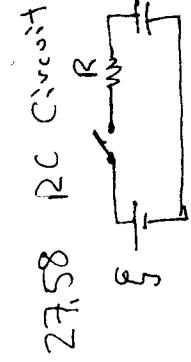
$$1.119 \text{ Volts}$$

This is also the pot'l difference
across R_1 .

The percent difference in the two
values is

$$\frac{1.15 - 1.119}{1.15} = 2.66 \times 10^{-2}$$

$$= 2.66 \%$$



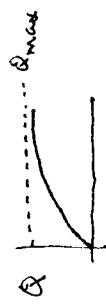
$$\begin{aligned} E &= 12 \text{ Volts} \\ R &= 1.4 \text{ M}\Omega = 1.4 \times 10^6 \Omega \\ C &= 1.8 \mu\text{F} = 1.8 \times 10^{-6} \text{ F} \end{aligned}$$

a) time constant $\tau = RC = (1.4 \times 10^6)(1.8 \times 10^{-6})$
 $= 2.52 \text{ sec}$

b) Max charge on capacitor.

The voltage on the capacitor will build up to 12 Volts
 $Q_{\max} = C V = (1.8 \times 10^{-6})(12) = 2.16 \times 10^{-5} \text{ Coulombs}$

c) How long until $Q = 16 \mu\text{C}$?

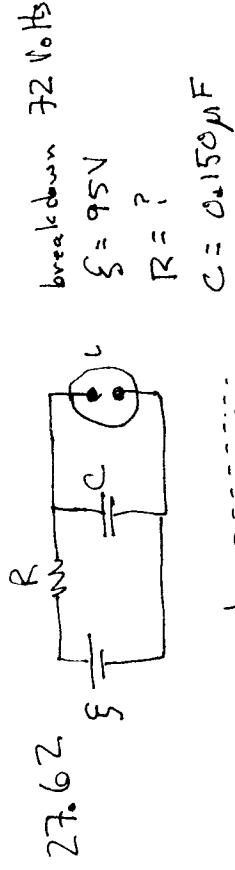


$$Q(t) = Q_{\max} [1 - e^{-t/\tau}]$$

$$16 \times 10^{-6} = 2.16 \times 10^{-5} [1 - e^{-t/2.52}]$$

take ln() $0.259 = -t/2.52$
 $-1.35 = -t/2.52$

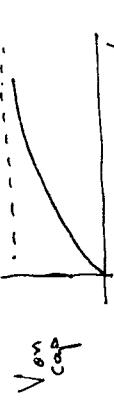
$$t = 3.40 \text{ sec}$$



$$E = 95 \text{ V}$$

$$R = ?$$

$$C = 0.15 \mu\text{F}$$



$$V_{cap}(t) = E [1 - e^{-t/RC}]$$

$$72 = 95 [1 - e^{-t/RC}]$$

$$0.242 = e^{-t/RC}$$

$$t = 0.5 \text{ sec}$$

$$1.418 = \frac{0.5}{RC}$$

$$1.418 = \frac{0.5}{R(0.15 \times 10^{-6})}$$

$$R = 2.35 \times 10^6 \Omega$$

$$= 2.35 \text{ M}\Omega$$