26.47


Nichrome wire
$A = 2.6\times10^{-6}\,m^2$
$\rho = 5\times10^{-7}\,\Omega m$
$\Delta V = 75$ Volts

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

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

$R = 1.125\,\Omega$

then

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

$1.125 = (5\times10^{-7})\frac{L}{2.6\times10^{-6}}$

$L = 5.85$ meters

b) Repeat with $\Delta V = 100$ Volts

Power $= IV \rightarrow \frac{V^2}{R}$

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

$R = 0.5\,\Omega$

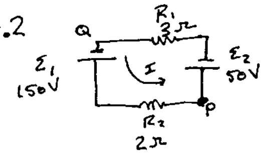
then

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

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

$L = 2.6$ meters

27.2




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

$\mathcal{E}_1 - IR_2 - \mathcal{E}_2 - IR_1 = 0$

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

$100 - I5 = 0$

$I = 20$ 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 $-150$

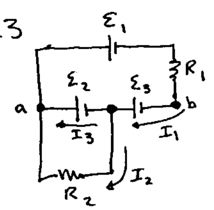
So

$100 + IR_2 - 150$

$100 + 20(2) - 150$

$-10$ Volts

27.23




$\mathcal{E}_1 = 6$ V
$\mathcal{E}_2 = 5$ V
$\mathcal{E}_3 = 4$ V
$R_1 = 100\,\Omega$
$R_2 = 50\,\Omega$

$I_1 = I_2 + I_3$

Start SE corner, do upper loop, CW

$\mathcal{E}_3 + \mathcal{E}_2 - \mathcal{E}_1 - I_1R_1 = 0$

Start at middle junction, go CW around bottom loop

$-I_2R_2 - \mathcal{E}_2 = 0$

Now re write 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

$I_1 = I_2 + I_3$

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

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

Then

$I_1 = I_2 + I_3$

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

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

$\frac{10-3}{100} = I_3 \rightarrow I_3 = \frac{7}{100}$

Summarizing

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

Then to get the potential difference between a & b.
Suppose we start at b with $V_b$
get boosted by $\mathcal{E}_3$
get boosted by $\mathcal{E}_2$
Arrive at a with $V_a$

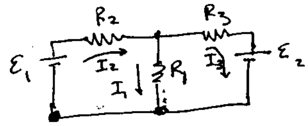
$V_b + \mathcal{E}_3 + \mathcal{E}_2 = V_a$

$\mathcal{E}_3 + \mathcal{E}_2 = V_a - V_b$

$4 + 5 = V_a - V_b$

$9 = V_a - V_b$

27.36




$\mathcal{E}_1 = 6$
$\mathcal{E}_2 = 12$
$R_1 = 100\,\Omega$
$R_2 = 200\,\Omega$
$R_3 = 300\,\Omega$

$I_2 = I_1 + I_3$

start SW corner, go CW around left loop

$$\mathcal{E}_1 - I_2 R_2 - I_1 R_1 = 0$$

start middle-bottom, go CW arount right loop

$$-(-I_1) R_1 - I_3 R_3 - \mathcal{E}_2 = 0$$

Now rewrite, filling ~~in~~ the values

[1] $I_2 = I_1 + I_3$

[2] $6 - I_2\,200 - I_1\,100 = 0$

[3] $+ I_1\,100 - I_3\,300 - 12 = 0$

Eliminate $I_2$ in [2] using [1]

[1] $I_2 = I_1 + I_3$

[2]' : $6 - (I_1 + I_3)\,200 - I_1\,100 = 0$

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

[3] $I_1\,100 - I_3\,\cancel{300} - 12 = 0$

Solve [3] for $I_1$ and ~~then~~ plug in [2]'

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

$I_1\,100 = 12 + I_3\,300$

$I_1 = \dfrac{12 + I_3\,300}{100}$

[2]' : $6 - I_1\,300 - I_3\,200 = 0$

$6 - \left[\dfrac{12 + I_3\,300}{1\cancel{00}}\right] 3\cancel{00} - I_3\,200 = 0$

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

$-30 - I_3\,1100 = 0$

$- I_3\,1100 = 30$

$I_3 = \dfrac{-30}{1100} = -0.02727$ Amp

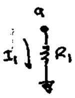
Then to get $I_1$

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

$= 0.03818$ Amp

Then to get $I_2$

$I_2 = I_1 + I_3 = 0.03818 + -0.02727$
$= 0.01091$ Amp



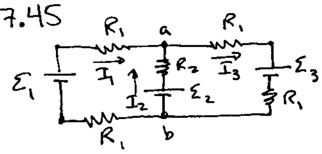

If the bottom of the circuit is zero volts must climb through $R_1$ to get to a.

$0 - (-I_1)R_1 = V_a$

$0.03818\,(100) = V_a$

$3.818$ Volts $= V_a$

27.45




$\mathcal{E}_1 = 2$
$\mathcal{E}_2 = 4$
$\mathcal{E}_3 = 4$
$R_1 = 1$
$R_2 = 2$

$I_1 + I_2 = I_3$

start SW corner, go CW around left loop.

$$\mathcal{E}_1 - I_1 R_1 - (-I_2)R_2 - \mathcal{E}_2 - I_1 R_1 = 0$$

start middle bottom, go CW around right loop

$$\mathcal{E}_2 - I_2 R_2 - I_3 R_1 - \mathcal{E}_3 - I_3 R_1 = 0$$

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

[1] $I_1 + I_2 = I_3$

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

$-2I_2 - I_3 - I_3 = 0$

$-2I_2 - 2I_3 = 0$

[3] $I_2 + I_3 = 0$

Simplify

[1] $I_1 + I_2 = I_3$

[2]' $-1 - I_1 + I_2 = 0$

[3] $I_2 + I_3 = 0$

Substitute [3] into [1]

$I_3 = -I_2$

$I_1 + I_2 = I_3$

$I_1 + I_2 = -I_2$

$I_1 + 2I_2 = 0$

$I_1 = -2I_2$

plug this into [2]'

$-1 - I_1 + I_2 = 0$

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

$-1 + 2I_2 + I_2 = 0$

$-1 + 3I_2 = 0$

$I_2 = 1/3$

then

$I_1 = -2I_2 = -2(1/3)$
$= -2/3$

then

$I_1 + I_2 = I_3$

$-2/3 + 1/3 = I_3$

$I_3 = -1/3$

Potential Difference

Start at b with $V_b$
cross $\mathcal{E}_2$
go through $R_2$ $\quad -I_2 R_2$
arrive at a with $V_a$

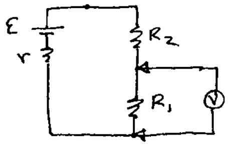
So $V_b + \mathcal{E}_2 - I_2 R_2 = V_a$

$\mathcal{E}_2 - I_2 R_2 = V_a - V_b$

$4 - 1/3(2) = V_a - V_b$

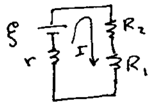
$\frac{10}{3} = V_a - V_b$

27.53




$\mathcal{E} = 3$
$r = 100\ \Omega$
$R_1 = 250\ \Omega$
$R_2 = 300\ \Omega$

Ideally the circuit is




The current can be calculated as

$$\mathcal{E} - Ir - IR_2 - IR_1 = 0$$

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

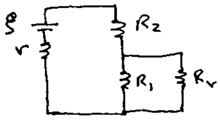
$$= 4.615\ mA$$

And the potential difference across $R_1$ is

$$IR_1 = (4.615\,mA)\ 250\ \Omega$$

$$= 1.15\ \text{Volts}$$

If the voltmeter is cheap, it will load the circuit

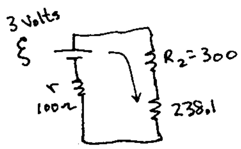



$R_v = 5\,k\Omega = 5000\ \Omega$

analyze this by combining resistors

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

$$R_{eff} = 238.10\ \Omega$$




The current is then

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

$$= 4.701\ mA$$

The pot'l difference across the 238.1 Ω resistance is

$$(4.701\,mA)(238.1\ \Omega)$$

$$1.119\ \text{Volts}$$

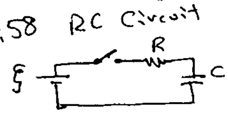
This is also the pot'l difference across $R_1$

The percent difference in the two values is

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

$$= 2.66\ \%$$

27.58 RC Circuit




$\mathcal{E} = 12$ Volts
$R = 1.4\ M\Omega = 1.4 \times 10^{6}\ \Omega$
$C = 1.8\,\mu F = 1.8 \times 10^{-6} F$

a) time constant $\tau = RC = (1.4\times10^{6})(1.8\times10^{-6})$

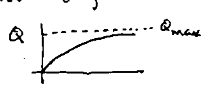
$$= 2.52\ \text{sec}$$

b) Max Charge on Capacitor.

The voltage on the capacitor will build up to 12 Volts

$$Q_{max} = CV_{max} = (1.8\times10^{-6})(12) = 2.16\times10^{-5}\ \text{Coulombs}$$

c) How long until $Q = 16\,\mu C$ ?




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

$$16\times10^{-6} = 21.6\times10^{-6}\left[1 - e^{-t/\tau}\right]$$

$$0.259 = e^{-t/\tau}$$

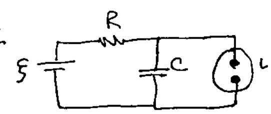
take ln( )

$$-1.35 = -t/\tau$$

$$1.35 = t/2.52$$

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

27.62




breakdown 72 Volts
$\xi = 95V$
$R = ?$
$C = 0.150\,\mu F$


$$V_{on\,cap}(t) = \xi\left[1 - e^{-t/RC}\right]$$

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

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

take ln( )

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

Want $t = 0.5\,sec$

$$1.418 = \frac{0.5}{R\,(0.15\times10^{-6})}$$

$$R = 2.35\times10^{6}\ \Omega$$

$$= 2.35\ M\Omega$$

## 26.47


Nichrome wire

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

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

$\Delta V = 75$ Volts

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

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

$R = 1.125\ \Omega$

then

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

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

$L = 5.85$ meters

b) Repeat with $\Delta V = 100$ Volts

$\text{Power} = IV \Rightarrow \frac{V^2}{R}$

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

$R = 0.5\ \Omega$

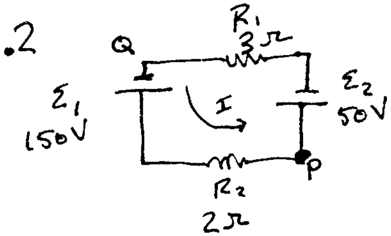
then

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

$0.5 = (5\text{-}7) \frac{L}{(2.6\text{-}6)}$

$L = 2.6$ meters

## 27.2




First figure out the current in the circuit.

Start at Q and go CCW

$\mathcal{E}_1 - IR_2 - \mathcal{E}_2 - IR_1 = 0$

$150 - I2 - 50 - I3 = 0$

$100 - I5 = 0$

$I = 20$ Amps

Now to answer the question.

We start at P with 100 Volts

we climb backwards through the resistor $-(-I)R_2$

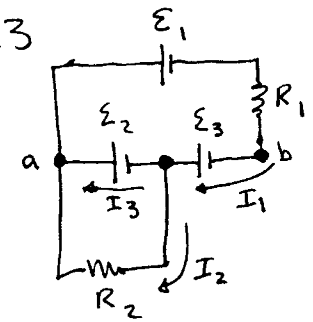
we go across the battery the wrong way $-150$

So $100 + IR_2 - 150$

$100 + 20(2) - 150$

$-10$ Volts

27.23




$\mathcal{E}_1 = 6$ V
$\mathcal{E}_2 = 5$ V
$\mathcal{E}_3 = 4$ V
$R_1 = 100\ \Omega$
$R_2 = 50\ \Omega$

$$I_1 = I_2 + I_3$$

start SE corner, do upper loop, CW

$$\mathcal{E}_3 + \mathcal{E}_2 - \mathcal{E}_1 - I_1R_1 = 0$$

start at middle junction, go CW around bottom loop

$$-I_2R_2 - \mathcal{E}_2 = 0$$

Now re write 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

$$I_1 = I_2 + I_3$$
$$-3 - I_1\,100 = 0 \longrightarrow I_1 = -3/100$$
$$-I_2 50 - 5 = 0 \longrightarrow I_2 = -1/10$$

Then

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

Summarizing

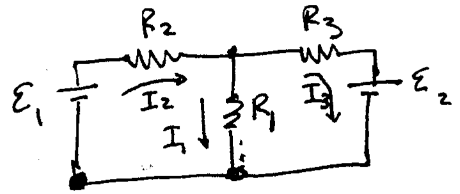
$$I_1 = -\frac{3}{100} \qquad I_2 = -\frac{1}{10} = -\frac{10}{100} \qquad I_3 = \frac{7}{100}$$

Then to get the potential difference between a & b.

Suppose we start at b with $V_b$
get boosted by $\mathcal{E}_3$
get boosted by $\mathcal{E}_2$
Arrive at a with $V_a$

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

27.36




$\mathcal{E}_1 = 6$
$\mathcal{E}_2 = 12$
$R_1 = 100\,\Omega$
$R_2 = 200\,\Omega$
$R_3 = 300\,\Omega$

$$I_2 = I_1 + I_3$$

start SW corner, go CW around left loop

$$\mathcal{E}_1 - I_2 R_2 - I_1 R_1 = 0$$

start middle-bottom, go CW around right loop

$$-(-I_1) R_1 - I_3 R_3 - \mathcal{E}_2 = 0$$

Now rewrite, filling ~~in~~ the values

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

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

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

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

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

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

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

$\boxed{3}$ $\quad I_1\, 100 - I_3\, \cancel{300} - 12 = 0$

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

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

$$I_1\, 100 = 12 + I_3\, 300$$

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

$\boxed{2}'$ : $\quad 6 - I_1\, 300 - I_3\, 200 = 0$

$$6 - \left[\frac{12 + I_3\, 300}{1\cancel{0}\cancel{0}}\right] 3\cancel{0}\cancel{0} - I_3\, 200 = 0$$

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

$$-30 - I_3\, 1100 = 0$$

$$-I_3\, 1100 = 30$$

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

Then to get $I_1$

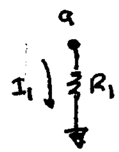
$$I_1 = \frac{12 + I_3\, 300}{100} = \frac{12 + -\frac{30}{1100}\, 300}{100}$$

$$= 0.03818 \text{ Amp}$$

Then to get $I_2$

$$I_2 = I_1 + I_3 = 0.03818 + {}^{-}0.02727$$

$$= 0.01091 \text{ Amp}$$



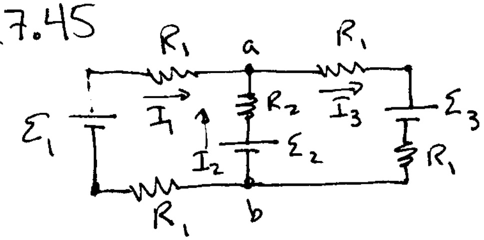

If the bottom of the circuit is zero volts must climb through $R_1$ to get to a.

$$0 - (-I_1) R_1 = V_a$$

$$0.03818\,(100) = V_a$$

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

27.45




$\varepsilon_1 = 2$
$\varepsilon_2 = 4$
$\varepsilon_3 = 4$
$R_1 = 1$
$R_2 = 2$

$$I_1 + I_2 = I_3$$

start SW corner, go CW around left loop.

$$\varepsilon_1 - I_1 R_1 - (-I_2) R_2 - \varepsilon_2 - I_1 R_1 = 0$$

start middle bottom, go CW around right loop

$$\varepsilon_2 - I_2 R_2 - I_3 R_1 - \varepsilon_3 - I_3 R_1 = 0$$

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

$\boxed{1}$ $I_1 + I_2 = I_3$

$\boxed{2}$ $-2 - 2I_1 + 2I_2 = 0$

$-2I_2 - I_3 - I_3 = 0$

$-2I_2 - 2I_3 = 0$

$\boxed{3}$ $I_2 + I_3 = 0$

Simplify

$\boxed{1}$ $I_1 + I_2 = I_3$

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

$\boxed{3}$ $I_2 + I_3 = 0$

Substitute $\boxed{3}$ into $\boxed{1}$

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

plug this into $\boxed{2}'$

$$-1 - I_1 + I_2 = 0$$
$$-1 - (-2I_2) + I_2 = 0$$
$$-1 + 2I_2 + I_2 = 0$$
$$-1 + 3I_2 = 0$$
$$I_2 = 1/3$$

then

$$I_1 = -2I_2 = -2(1/3)$$
$$= -2/3$$

then

$$I_1 + I_2 = I_3$$
$$-2/3 + 1/3 = I_3$$
$$I_3 = -1/3$$

Potential Difference

Start at b with $V_b$

cross $\varepsilon_2$

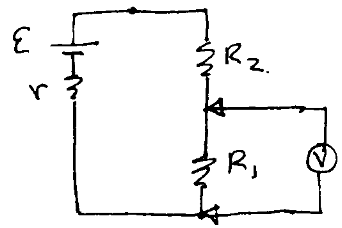
go through $R_2$ $\quad -I_2 R_2$

arrive at a with $V_a$

So

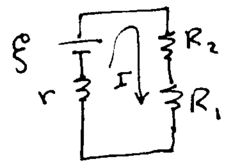
$$V_b + \varepsilon_2 - I_2 R_2 = V_a$$
$$\varepsilon_2 - I_2 R_2 = V_a - V_b$$
$$4 - 1/3(2) = V_a - V_b$$
$$\frac{10}{3} = V_a - V_b$$

27.53




$\mathcal{E} = 3$
$r = 100\ \Omega$
$R_1 = 250\ \Omega$
$R_2 = 300\ \Omega$

Ideally, the circuit is




The current can be calculated as

$$\mathcal{E} - Ir - IR_2 - IR_1 = 0$$

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

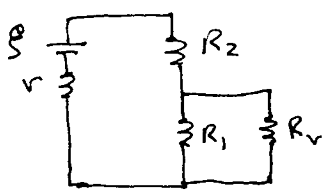
$$= 4.615\ \text{mA}$$

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

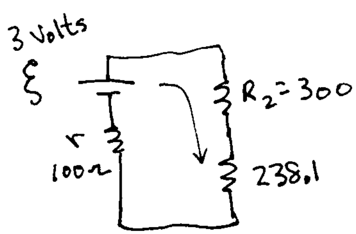



$R_v = 5\,k\Omega = 5000\ \Omega$

analyze this by combining resistors

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

$$R_{eff} = 238.10\ \Omega$$




The current is then

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

$$= 4.701\ \text{mA}$$

The pot'l difference across the 238.1 Ω resistance is

$$(4.701\,\text{mA})(238.1\ \Omega)$$

$$1.119\ \text{Volts}$$

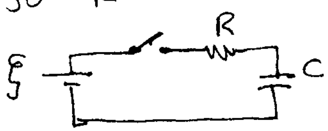
This is also the pot'l difference across $R_1$

The percent difference in the two values is

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

$$= 2.66\ \%$$

27.58 RC Circuit




$\mathcal{E} = 12$ Volts

$R = 1.4\ M\Omega = 1.4\times10^{6}\ \Omega$

$C = 1.8\mu F = 1.8\times10^{-6} F$

a) time constant

$\tau = RC = (1.4\times10^{6})(1.8\times10^{-6})$

$= 2.52$ sec

b) Max Charge on Capacitor.

The voltage on the capacitor will build up to 12 Volts

$Q_{max} = CV_{max} = (1.8\times10^{-6})(12) = 2.16\times10^{-5}$ Coulombs

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


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

$16\times10^{-6} = 21.6\times10^{-6}\left[1 - e^{-t/\tau}\right]$

$0.259 = e^{-t/\tau}$

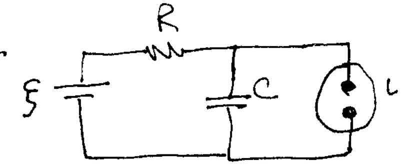
take ln( )

$-1.35 = -t/\tau$

$1.35 = t/2.52$

$t = 3.40$ sec

27.62

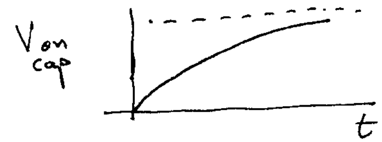



breakdown 72 Volts

$\xi = 95V$

$R = ?$

$C = 0.150\mu F$




$V_{on\ cap}(t) = \xi\left[1 - e^{-t/RC}\right]$

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

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

take ln( )

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

Want $t = 0.5$ sec

$1.418 = \frac{0.5}{R(0.15\times10^{-6})}$

$R = 2.35\times10^{6}\ \Omega$

$= 2.35\ M\Omega$