LECTURE 2/16

READ CH 28

FINISH DISCUSSION ON RESISTIVITY FIRST

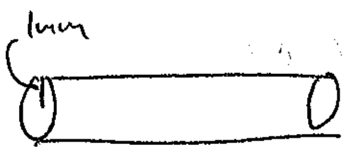
EXAMPLE

CALCULATING ~~RESISTIVITY~~ RESISTANCE ~~OF UNIT~~ PER UNIT LENGTH OF A NICHROME WIRE WITH ~~DIAMETER~~ RADIUS OF 1mm

NICHROME WIRE

$$\rho = 1.5 \times 10^{-6}\ \Omega \cdot m$$

$\pi r^2$




$$A = \pi r^2$$

$$= \cancel{\phi}(1 \times 10^{-3})^2 m\ 3.14$$

$$= 3.14 \times 10^{-6}\ m^2$$

$$R = \frac{\rho l}{A} \Rightarrow \cancel{1.5 \times 10^{-6}\ \Omega m}$$

$$R/l = \frac{\rho}{A} = \frac{1.5 \times 10^{-6}\ \Omega \cdot m}{3.14 \times 10^{-6}\ m^2}$$

$$\cong \underline{0.5\ \Omega/m}$$

IF 10V IS APPLIED ACROSS NICHROME WIRE THAT IS 1m IN LENGTH

$V = IR$

$10 = 0.5\,I$

$\boxed{I = 20A}$

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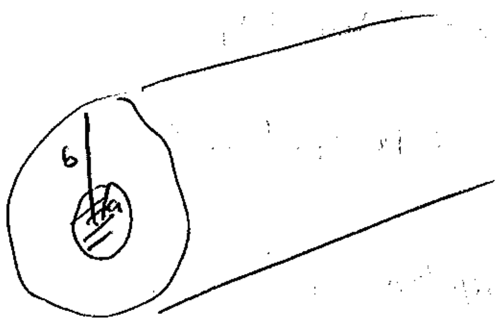
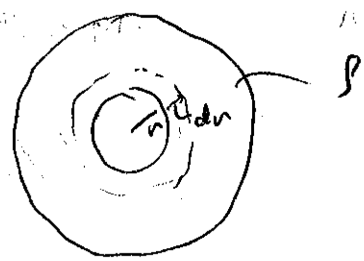
RESISTIVITY OF CONCENTRIC COAX




$R = \dfrac{\rho\, l}{A}$




$= \dfrac{\rho\, dr}{2\pi r}$

$R = \dfrac{\rho}{2\pi}\displaystyle\int_a^b \frac{dr}{r}$

$= \dfrac{\rho}{2\pi} \ln r \Big]_a^b$

$= \dfrac{\rho}{2\pi} \ln \dfrac{b}{a}$

MODEL FOR CONDUCTION

$$\vec{J} = \sigma \vec{E}$$

$\vec{J}$ = CURRENT / UNIT AREA

CURRENT = $\underline{n\, e} \cdot V_{drift}$

$\vec{F} = e\vec{E}$ SO IT SPEEDS UP

$ma = e\vec{E}$

$a = \frac{eE}{m}$ IF IT GOES FOR $\tau$ BEFORE SCATTERING COMPLETELY TURNED

$$\bar{V}_d = \frac{eE}{m}\tau$$

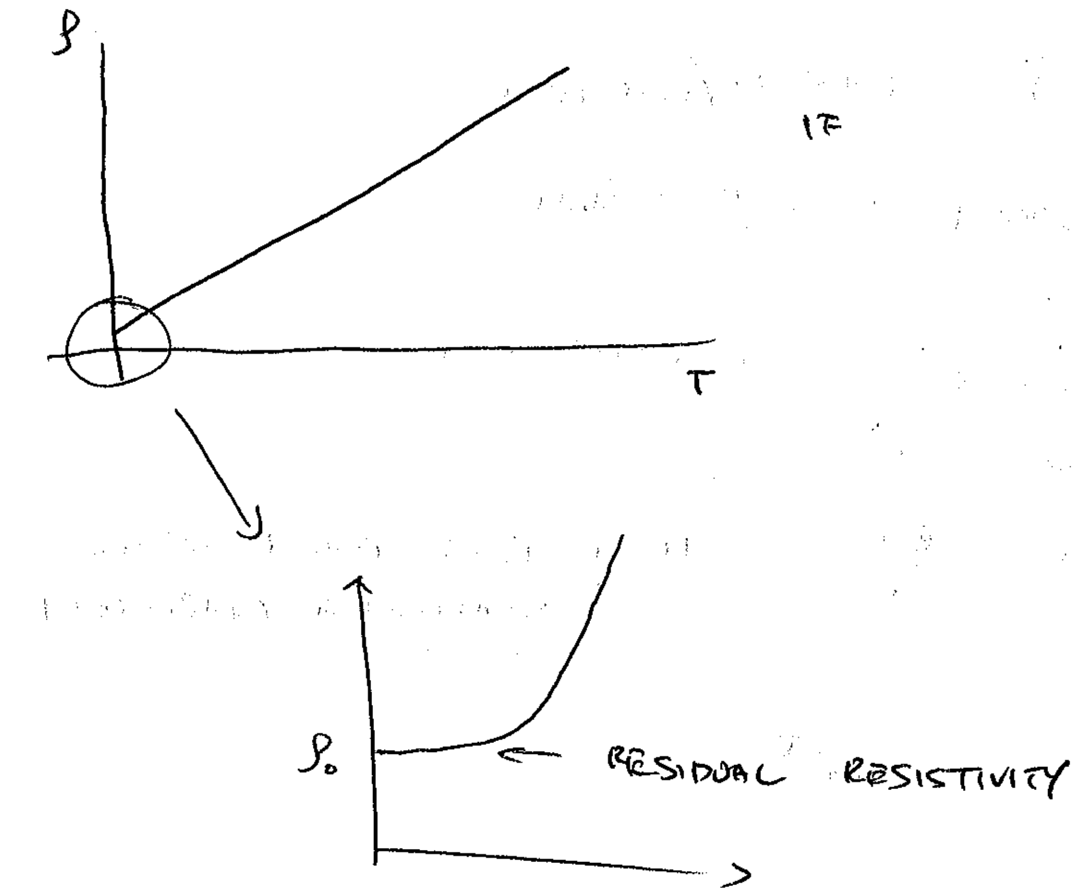
$$\vec{J} = n\, e\, \frac{eE}{m}\tau$$

$$\vec{J} = \frac{ne^2\tau\vec{E}}{m}$$

$$\boxed{\sigma = \frac{ne^2\tau}{m}}$$

DRUDE MODEL

## RESISTANCE AND TEMPERATURE

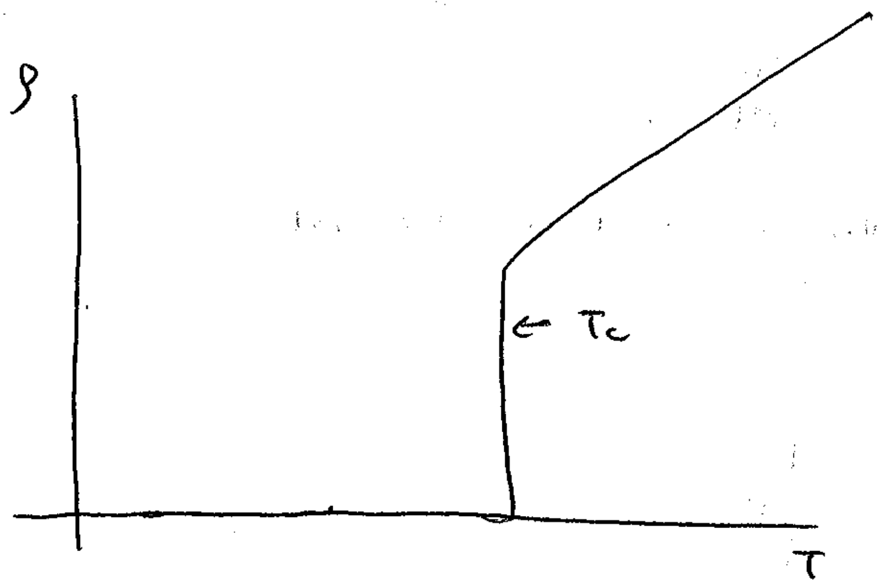



IF

IF $\dfrac{d\rho}{dT} \geq 0$ METAL

$\dfrac{d\rho}{dT} < 0$ SEMICONDUCTOR

SUPER CONDUCTORS  1911 HEIKE KAMERLIGN-ONNES




$T_c$ = 134K  $HgBa_2Ca_2Cu_3O_8$

Zn  0.85K

Nb  9.46K

$\boxed{R=0}$

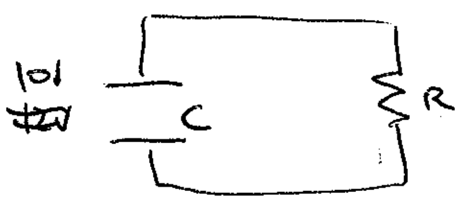
WED?

## ELECTRICAL POWER

ENERGY J : JOULES $mgh$.

**POWER** $\frac{dE}{dt}$.

FAST V.S. SLOW MOVING STUDENT



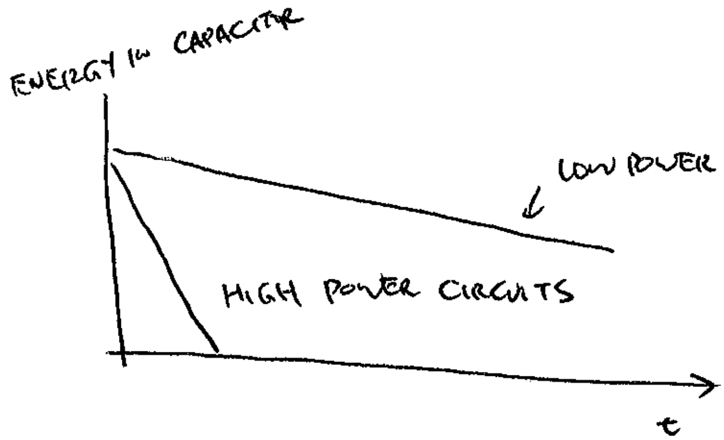

$C = 100\ \mu FD$

ENERGY STORED

$$\frac{Q^2}{2C} = \frac{1}{2}CV^2 = \frac{1}{2}\,100\times10^{-6}\ 10^2 = \frac{10^{-4}}{2}\cdot 100 = \frac{1}{2}\,10^{-2}$$

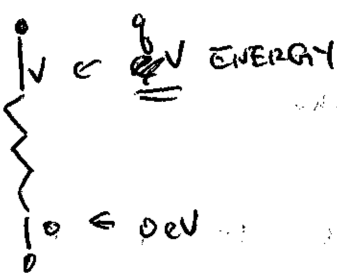
$$= 0.5\times10^{-2}\ J$$

$$= \boxed{5\ mJ}$$




POWER


$$I = \frac{V}{R} = \frac{dq}{dt}$$ # OF CHARGE PER UNIT TIME




ENERGY DISSIPATED

$= qV$

∴ POWER ENERGY DISSIPATED PER UNIT

$$\frac{dE}{dt} = \frac{d}{dt}(qV)$$

$$= V\frac{dq}{dt}$$

$$\boxed{P = IV}$$

EXAMPLE.

120V ACROSS $8\Omega$

$$I = \frac{120V}{8\Omega} = 15A$$

$$P = 15A \cdot 120V = 1800\,W = \underline{1.8kW}$$

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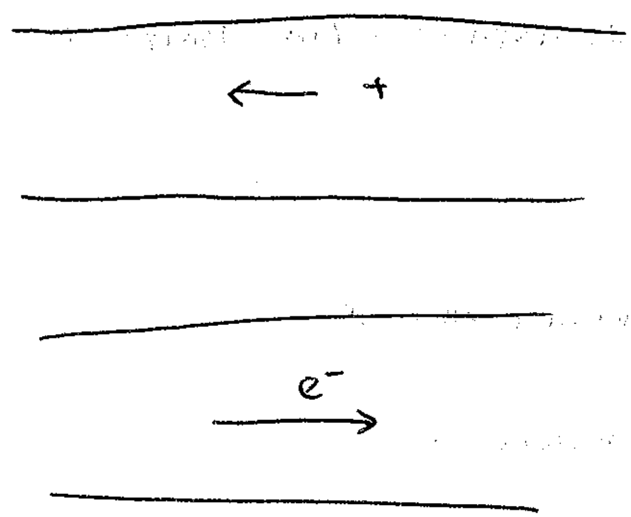
8 BATTERIES 4K Whr

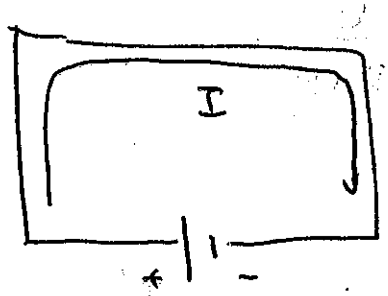
IF SOMETHING TAKES 1000W TO RUN

IT TAKES 4hrs TO GO EMPTY

# DIRECTION OF CURRENT

EQUIVALENT STATEMENT




BECAUSE OF INITIAL CONVENTION

~~EXAMPLE~~

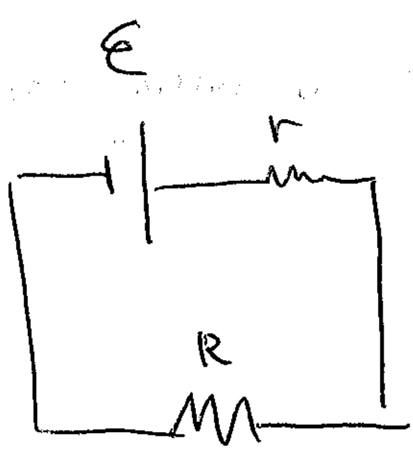
ELECTRO MOTIVE FORCE : MAX VOLTAGE BATTERIES CAN PROVIDE

INTERNAL RESISTANCE : RESISTANCE W/IN BATTERY

$\Delta V = \mathcal{E} - Ir$

$\mathcal{E}$ : OPEN CIRCUIT VOLTAGE

R : LOAD RESISTANCE




$I = \dfrac{\mathcal{E}}{R+r}$

$I\mathcal{E} = I^2R + I^2r$ = POWER DELIVERED

I =

FOR EXAMPLE

A BATTERY CAN HAVE EMF OF 12V AND INTERNAL RESISTANCE OF $0.05\,\Omega$ LOAD RESISTANCE IS $3.0\,\Omega$

a) FIND CURRENT

$$\frac{12}{3.05\,\Omega} = 3.93\,A$$

b) POWER DELIVERED TO THE RESISTOR

$$I^2R = (3.93A)^2 \cdot 3.0\Omega = 46.3W$$

POWER DELIVERED TO THE INTERNAL RESISTOR

$$I^2R,\ I^2r = (3.93A)^2 \cdot 0.05\Omega = 0.772W$$

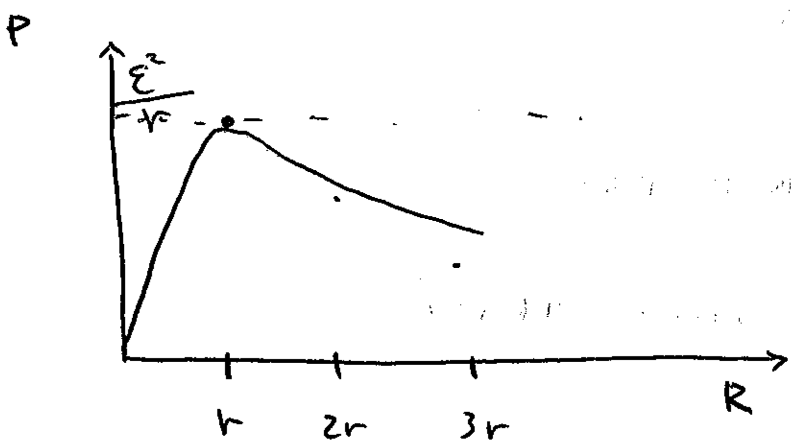
TOTAL POWER

$$46.3W + 0.772W = 47.1W$$

FIND R FOR WHICH THE MAX POWER IS DELIVERED TO THE LOAD

$$I = \frac{\mathcal{E}}{R+r}$$

$$P = I^2 R = \frac{\mathcal{E}^2}{(R+r)^2} R$$




$$\frac{dP}{dR} = \frac{\mathcal{E}^2}{(R+r)^2} - \frac{2\,\mathcal{E}^2\,R}{(R+r)^3}$$

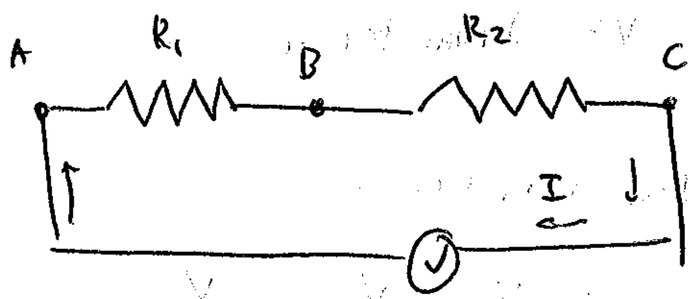
$$= \mathcal{E}^2 \frac{1}{(R+r)^3}\left[ R + r - 2R \right] = 0$$

$$\mathcal{E}\frac{[-R+r]}{(R+r)^3} = 0$$

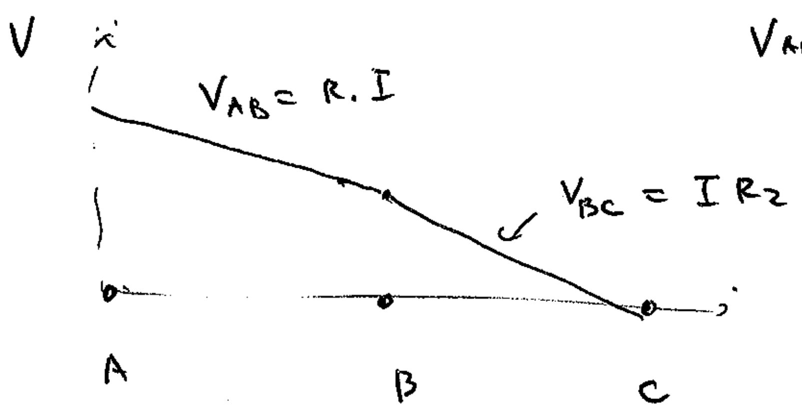
$$\boxed{R = r}$$

# RESISTORS IN PARALLEL AND SERIES

~~(KIRKOFF'S RULES)~~

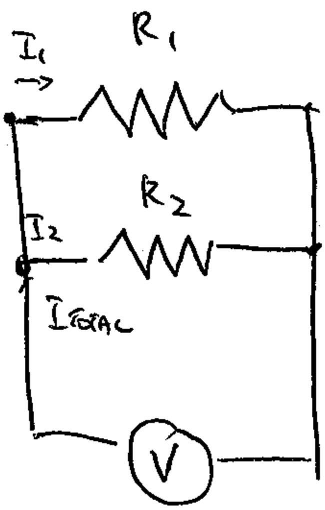



$\cancel{IR}$ $\quad I R_{TOTAL} = V$




$V_{AB} + V_{BC} = V = I(R_1 + R_2)$

$R_{TOTAL} = R_1 + R_2$




$$V = I_1 R_1$$

$$V = I_2 R_2$$

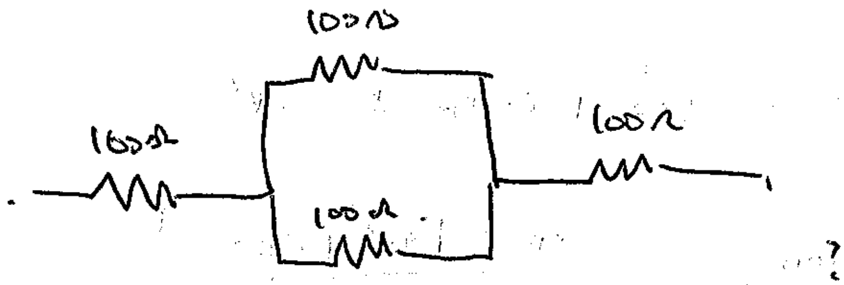
$$V = I_{TOTAL} R_{TOTAL}$$

$$I_{TOTAL} = I_1 + I_2$$

$$= \frac{V}{R_1} + \frac{V}{R_2} = \frac{V}{R_{TOTAL}}$$

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

EXAMPLE

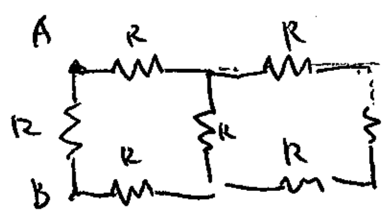



$$\frac{1}{100} + \frac{1}{100} = \frac{1}{R_{PT}}$$

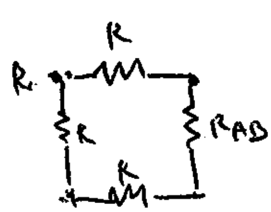
$R_{ST} = 50\Omega$

$\boxed{250\Omega}$

WHAT ABOUT




$R_{AB}$?




$$\frac{1}{R_{AB}} = \frac{1}{R} + \frac{1}{2R + R_{AB}}$$

$$\frac{1}{R_{AB}} = \frac{2R + R_{AB} + R}{R(2R + R_{AB})}$$

$$\frac{1}{R_{AB}} = \frac{3R + R_{AB}}{2R^2 + R_{AB}R}$$

$$2R^2 + R_{AB} R = 3 R R_{AB} + R_{AB}^2$$

$$0 = R_{AB}^2 + 2R R_{AB} \cancel{+} - 2R^2$$

$$R_{AB} = \frac{-2R \pm \sqrt{4R^2 + 8R^2}}{2}$$

$$= -R \pm \sqrt{3} R$$

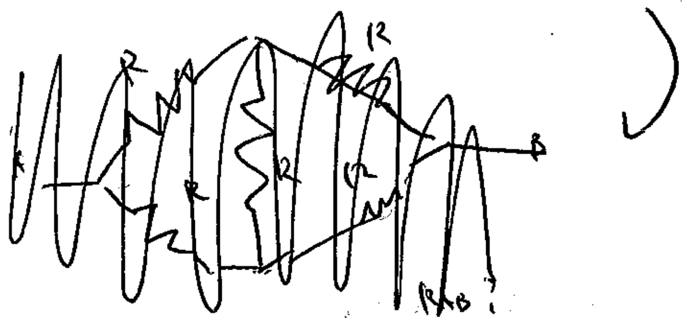
$$\boxed{= R(\sqrt{3} - 1)}$$

EXAMPLE.

~~FIND EQUIVALENT RESISTANCE~~

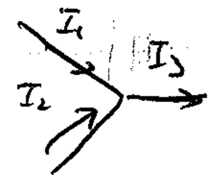

$$\cancel{\frac{1}{3}+\frac{1}{3}+\frac{1}{3}=\frac{1}{R_{eq}}}$$

$$\cancel{R_{EQ} = 1\ \Omega}$$



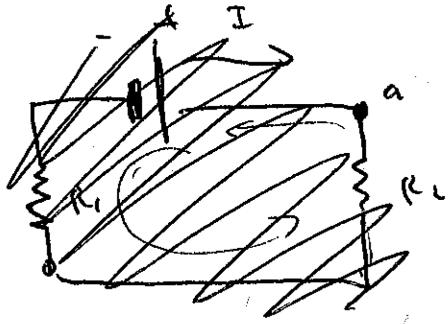

## KIRKOFF'S RULE'S

**1.** JUNCTION RULES $\qquad \sum I = 0$

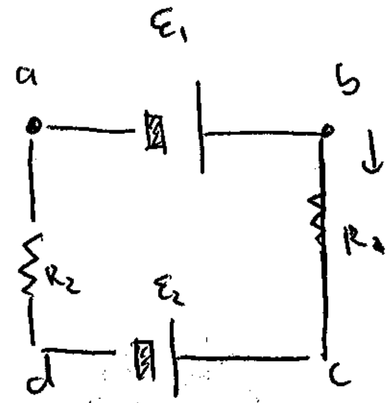



~~$I = I_2$~~ $\quad I_1 + I_2 - I_3 = 0$

2. LOOP RULE SUM OF POTENTIAL DIFFENCES ACROSS ALL ELEMENTS AROUND ANY CLOSED CIRCUITS MST BE ZERO



WHAT DOES IT MEAN?




$a \to b \quad +\mathcal{E}_1$

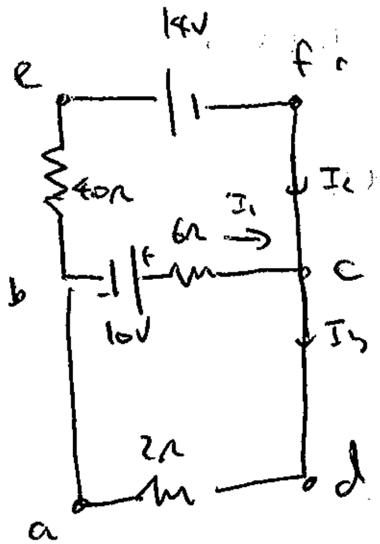
$b \to c \quad -IR_1$

$c \to d \quad -\mathcal{E}_2$

$d \to a \quad -IR_1$

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

EXAMPLE




FIND $I_1, I_2, I_3$

$I_1 + I_2 - I_3 = 0$ KIRCHOFF'S LAW

$abcda = 0 + 10V - I_1 6\Omega - I_3 2\Omega = 0$

$befcb = -I_2 4 - 14V + 6 I_1 - 10V = 0$

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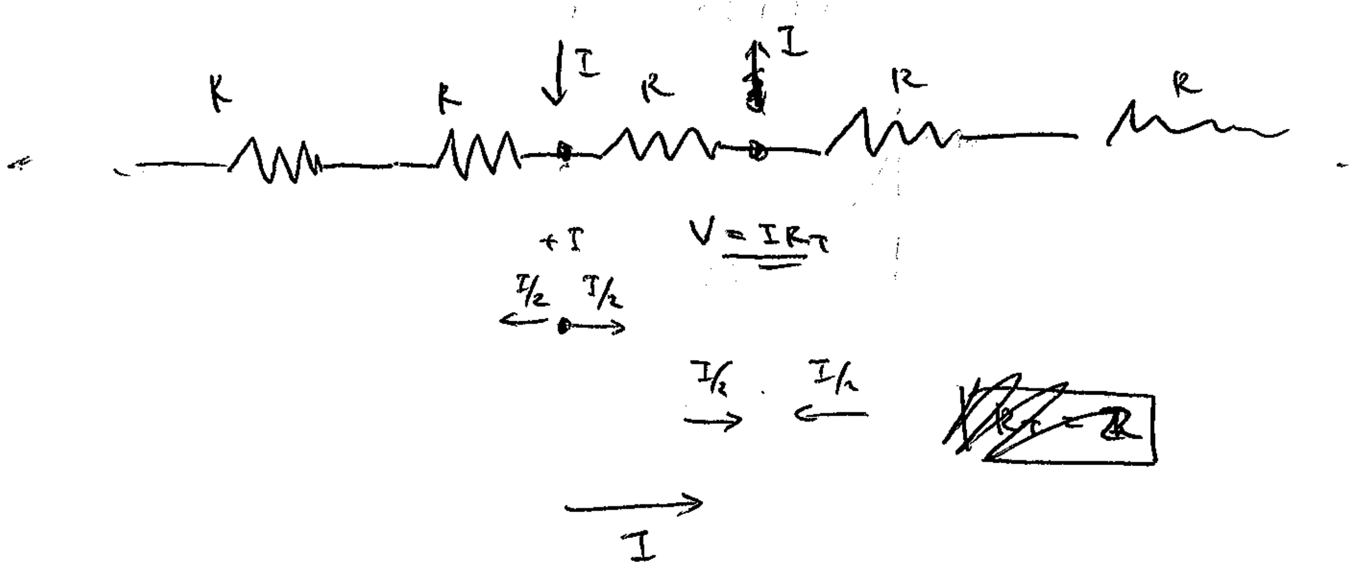
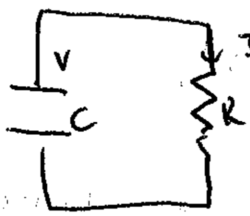
SUPER POSITION LINES



RC CIRCUITS

CAPACITOR




$V(t)$ $\qquad$ $Q(t)$

$$\frac{dQ}{dt} = I(t)$$

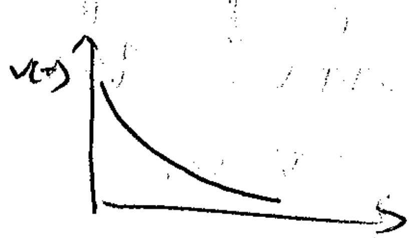
$$I = \frac{V(t)}{R}$$

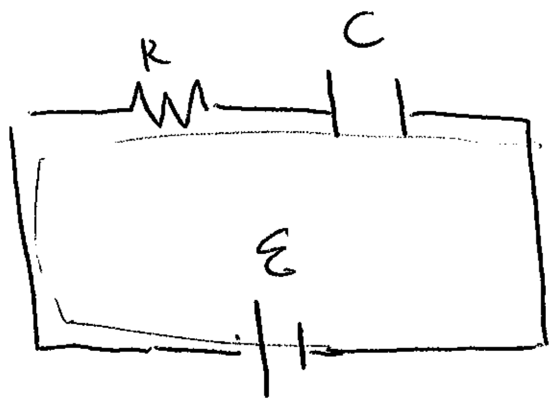
$$Q = CV$$

$$C\frac{dV}{dt} = \cancel{I}\,\frac{V(t)}{R}$$

$$\frac{dV}{dt} = \frac{V}{RC}$$

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






?

KIRCHOFF'S LAW

$$\mathcal{E} - \cancel{IR} \; IR - \frac{q}{C} = 0$$

$$\mathcal{E} - \frac{dq}{dt}R - \frac{q}{C} = 0$$

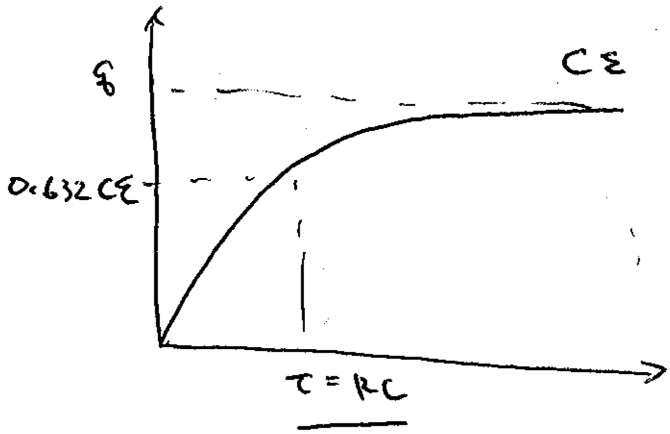
$$\frac{dq}{dt} = \frac{\mathcal{E}}{R} - \frac{q}{RC}$$

$$= \frac{\mathcal{E}C - q}{RC}$$

?

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

$$\tau = RC$$




τ, RC

MONDAY EM 367 OHM'S LAW

WED EM 373 LIGHT BULBS, EM 361 HAND BATTERY

FRIDAY EM ~~3~~ 382 DISCHARGE THRU A VOLTMETER