Chapter 1 $\boxed{DC}$: due to linear function of time referring to charges.

current $= \frac{dq}{dt} = A \rightarrow \frac{dq}{dt} = \alpha = \frac{\Delta q}{\Delta t}$ $\quad I = \frac{\Delta q}{\Delta t}$

charge $= \int_0^t i(t)\,dt = c + q(0)$ = number of electrons × electron charge.

$\boxed{\text{voltage} \Rightarrow}$

$V_{ab} = \frac{dw}{dq} = \frac{\Delta w}{\Delta q}$ → w: energy in joules.

$\boxed{\text{knowing}}$ that $V_{ab} = V_a - V_b$

V_a → highest polarity

V_b → lowest polarity.

$\boxed{\text{Power}}$

$P = \frac{dw}{dt}$ = watts = $\boxed{\text{rate}}$ ← a case ~~special~~ ~~name~~

$\Delta w = P\Delta t$ → it can be taken by hours for unit (Wh)

$P = i(t) \cdot v(t)$ = $\boxed{\text{Instantanuous}}$ ← a case ~~a case~~

$w = \int p\,dt.$

Passive sign convension

i through (+) term

↳ $+i \cdot v = p$

+p: absorbed by element.

−p: supplied by element.

i through (−) term.

↳ $-i \cdot v = p$

+p: absorbed.

−p: supplied.

law of conservation of energy:-

total supplied power = total absorbed power

$\sum_{k=1}^{n} p = 0$ → k is an element.

$\boxed{(y - y_0) = \text{slope}\,(X - X_0)}$

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Chapter (2)

① $R = \frac{v}{i}$ → Voltage $v = +iR$ (through +ve term)

$v = -iR$ (" -ve term).

Basic Resistance

Note :- short circuit + open circuit are described in my notebook.

② $R = \frac{\rho L}{A}$

G | Conductance | :- $G = \frac{1}{R} = 8$.

22 problem

Power (dissipated) by a resister :-

$P = +i \cdot v = i^2 R = \frac{v^2}{R}$

KCL + current source replacement :-

$\Sigma I_n = \Sigma I_{out}$ → remember $I = \frac{V}{R}$.

| Replacement | use kcl to replace currents sources in parrallel [revise notebook]

KVL + voltage source replacement :-

$\Sigma V_t = 0$ → ~~remb~~ remember $v = iR$. (take care of passive sign conversion)

| Replacement | use kvl to replace (revise notebook).

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Series Resistors :-

→ The current stays the same for them all ✓ (all resistors)

→ ① Apply (KVL) to determine how it goes ✓ (it gives v_{eq})

→ ② $R_{eq} = R_1 + R_2 + \dots + R_n$

Then ① $\boxed{i = \frac{v}{R_{eq}}}$

Then ② $v_1 = \pm i.R = \frac{R_1}{R_{eq}} v$

$v_2 = \pm i.R = \frac{R_2}{R_{eq}} v$

Voltage divider rule

Parallel Resistors :

→ The voltage stays the same for them all ✓ (all resistors)

→ You can apply (KCL) to see more details.

→ $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \dots + \frac{1}{R_n}$

then $R_{eq} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \dots + \frac{1}{R_n}}$

A special case when $N = 2$:-

→ $R_{eq} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}} = \frac{R_1 R_2}{R_1 + R_2}$

Using Conductance :-

$G_k = \frac{1}{R_k} \rightarrow G_{eq} = \frac{1}{R_{eq}}$

$G_{eq} = G_1 + G_2 + \dots + G_n$

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Then we substitute that:-

$$i_k = \frac{\frac{1}{R_k} \cdot i}{\frac{1}{R_{eq}}} = \frac{G_k \cdot i}{G_{eq}}$$

↓

for a branch

The current divider rule

A special case when $N=2$:-

$$i_1 = \frac{R_2}{R_1+R_2} \cdot i \qquad i_2 = \frac{R_1}{R_1+R_2} \cdot i$$

So :-

i_1 is $\propto \frac{1}{R_1}$ and $\propto R_2$

i_2 is $\propto \frac{1}{R_2}$ and $\propto R_1$.

→ See the open and short circuits in the note book ✓

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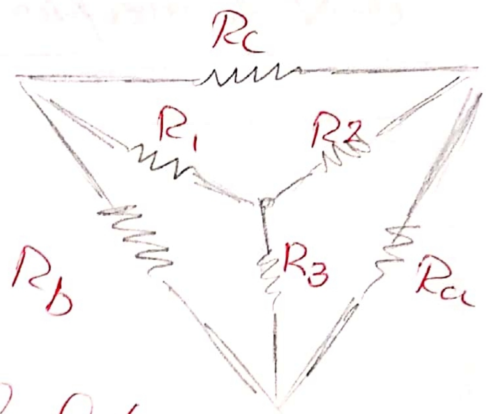
Delta – Wye Connections :-



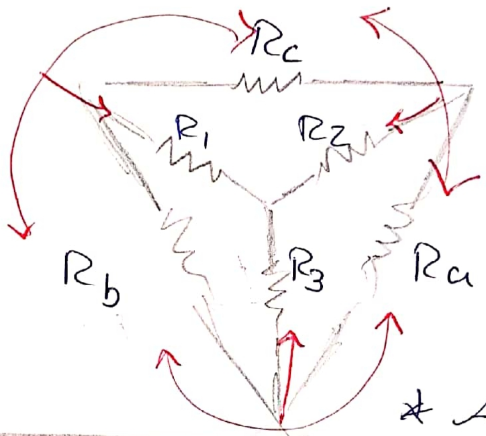
∇–Y conversion:-

① $R_1 = \dfrac{R_b \cdot R_c}{R_a + R_b + R_c}$

② $R_2 = \dfrac{R_a \cdot R_c}{R_a + R_b + R_c}$

③ $R_3 = \dfrac{R_a R_b}{R_a + R_b + R_c}$

So you can find it this way :-



* And for a special case:-

A Balanced ∇ connection

$R_a = R_b = R_c = R$

So you have a balanced Y connection:-

$R_1 = R_2 = R_3 = \dfrac{R}{3}$ ✓

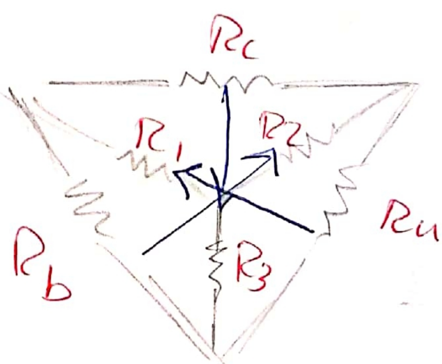
Y–∇ conversion:-

$R_a = \dfrac{R_1 R_2 + R_1 R_3 + R_2 R_3}{R_1}$

$R_b = \dfrac{R_1 R_2 + R_1 R_3 + R_2 R_3}{R_2}$

$R_c = \dfrac{R_1 R_2 + R_1 R_3 + R_2 R_3}{R_3}$

→ The Trick :-



chapter 3

[1] Nodal Analysis

→ select reference node.

→ ~~assaig~~ assign voltages v_1, v_2, v_3.

→ Apply KCl to nonreference node. (ohm's law applied.)

→ solve equations. ($Av=b$)

[2] Nodal Analysis with voltage sources.

case① → voltage source connected between reference and nonreference node. (put nonreference to voltage source)

case② → Apply kvl to super node.

→ then treat super node wire with anything in parallel with it, and then continue as usual.

*Cramers Rule:-

Example $Av=b$

$Det(A) = X$

$v_1 = \frac{Det_1}{Det(A)}$ (replace b in its column)

$v_2 = \frac{Det_2}{Det(A)}$ (replace b in 2nd column)

---

[3] Mesh Analysis.

→ assign mesh currents

→ Apply KVL /ohm's law applied.

→ Solve equation $AI=b$

[4] Mesh Analysis with current sources.

case ① I source only in one mesh → set mesh current to current source. consider directions

case② I source between 2 meshes. (supermesh)

→ exclude the current source and any elements connected in series with it.

linear property:-

function of transformation:-

to be linear:-

$$T\{\alpha_1 x_1(t) + \alpha_2 x_2(t)\} = \alpha_1 T\{x_1(t)\} + \alpha_2 T\{x_2(t)\}.$$

for:- $T\{i(t)\} = R \cdot i(t)$.

→ linear circuit:-

output is linearly related to its input.

Superpostion principle:-

principle of killing sources:-

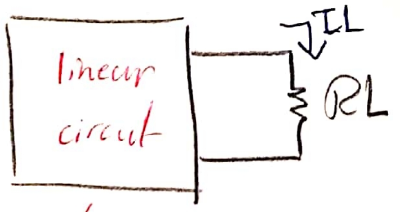
① Turn off all sources except one, and find the required thing.

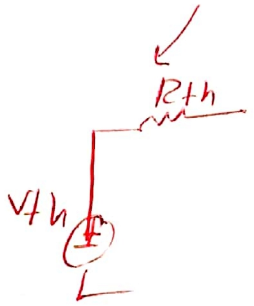
② repeat it for all sources

③ find total.

Thevenin Theorem

steps of finding R_{th} and V_{th} is in the note book.





$$I_L = \frac{V_{th}}{R_{th} + R_L}$$

$$V_L = \frac{R_L}{R_1 + R_{th}} \cdot R_{th}$$

apter 4 Analyzing circuit with each independent source
R POSITION acting alone, then use algebric sum.

→ - voltage sources are replaced by (short circuit)
- current sources are replaced by (open circuit).

→ Dependent sources are left intact.

Chapter 4

Source Transformation

replacing → a voltage source in series with R // by current source in parallel with R
↳ and vice versa.

$V_s = I_s R$ } for transformation.
$i_s = \frac{V_s}{R}$

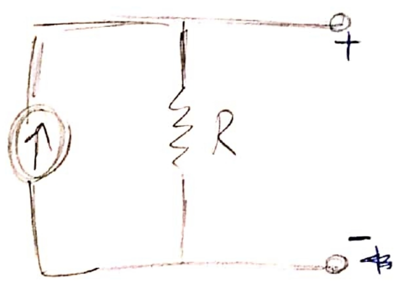
→ Applicable for independent and dependent sources.

Remember

→ we can combine 2 voltage sources additionally in series.

→ we can combine 2 current sources additionally in parallel.

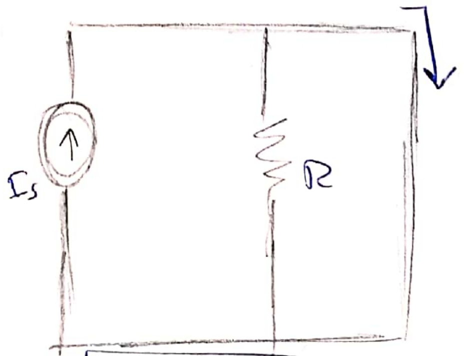
Open Circuit



$I_{op} = 0$

$V_{op} = V_s$ } $V_s = I_s R$

Short Circuit



$I_{sh} = I_s$
$V_{sh} = V_s$

$V_s = I_s R$

Chapter 6 summarization :-

§ 6.2 : capacitors (open circuits to dc)

voltage cannot change suddenly.

Basic

→ How to find capacitance :-

$C = \frac{q}{V}$ or $C = \frac{\epsilon d}{A}$ (A of one plate)
(q " " ")

c is measured in Farad = 1 columb / volt.

① → i through a capacitor :-

$i = c \frac{dv}{dt}$ → you'll find i(t) / function of t until they give you t

② → v(t) of capacitor :-

$$v(t) = \frac{1}{c} \int_{t_0}^{t} i(\tau)\, d\tau + v(t_0)$$

$$= \frac{1}{c} \int_{0}^{t} i(t)\, dt + v(t_0)$$

[Power and Energy :-

* Power

→ $p(t) = i(t) \cdot v(t)$

$p(t) = c \frac{dv(t)}{dt} \cdot v(t)$

* Energy stored in capacitor :

→ $w = \frac{1}{2} c v^2$

convert using $c = \frac{q}{v}$

→ or $w = \frac{1}{2} \frac{q^2}{c}$

voltage-division rule (capacitors in series)

$v_1 = \frac{C_2}{C_1+C_2} v_S$, $v_2 = \frac{C_1}{C_1+C_2} v_S$

current-division rule (capacitors in parallel)

$i_1 = \frac{C_1}{C_1+C_2} i_S$, $i_2 = \frac{C_2}{C_1+C_2} i_S$

:-

to dc)

enly.

→ How to find capacitance :-

$C = \frac{q}{V}$ or $C = \frac{\epsilon d}{A}$ (A of one plate)
(q " " ")

c is measured in Farad = 1 columb / volt.

① i through a capacitor:-

$i = C\frac{dv}{dt}$ → you'll find i(t) / function of t until they give you t

② v(t) of capacitor:-

$v(t) = \frac{1}{C}\int_{t_0}^{t} i(\tau)\,d\tau + v(t_0)$

$= \frac{1}{C}\int_{0}^{t} i(t)\,dt + v(t_0)$

[Power and Energy :-

* Power

→ $p(t) = i(t) \cdot v(t)$

$P(t) = C\frac{dv(t)}{dt} \cdot v(t)$

* Energy stored in capacitor:

→ $w = \frac{1}{2} C v^2$

convert using $C = \frac{q}{V}$

→ Series and parallel capacitors:

→ ~~Parallel resistors:~~

→ Parallel capacitors:

$C_{eq} = C_1 + C_2 + C_3 + C_4$

→ they share same voltage:
→ charge is distributed.

→ Series capacitors:

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \frac{1}{C_4}$$

→ They share same q
→ voltage is disributed.

special.
for N=2

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} \equiv C_{eq} = \frac{C_1 C_2}{C_1 + C_2}$$

Inductors:- a short circuit for dc.

→ current cannot change suddenly.

Basics:-

→ Inductance: $L = \frac{N^2 \mu A}{l}$

→ voltage:- $v = L\frac{di}{dt}$

→ current $i = \frac{1}{L}\int_{t_0}^{t} v(t)\,dt + i(t_0)$

for special case:-

$t_0 = -\infty \rightarrow i(t_0) = 0$

Then $i(t) = \frac{1}{L}\int_{-\infty}^{t} v(t)\,dt = \frac{1}{L}\left[\cancel{\int_{-\infty}^{0} v(t)\,dt} + \int_{0}^{t} v(t)\,dt\right] + i(0)$

power and energy:-

$\boxed{\text{series + parallel are like resistors}}$

$\rightarrow p = vi = \left(L\frac{di}{dt}\right) i$

$\rightarrow w = \frac{1}{2} L i^2$

we say under dc conditions, then:

$w_C = \frac{1}{2}CV^2 \,/\, w_L = \frac{1}{2}Li^2$

Voltage division principle:- (inductors in series)

$v_1 = \frac{L_1}{L_1+L_2} \times v_S$, $v_2 = \frac{L_2}{L_1+L_2} v_S$

for dc.

...lenly.

Current division principle (inductors in parallel)

$i_1 = \frac{L_2}{L_1+L_2} i_S$, $i_2 = \frac{L_1}{L_1+L_2} i_S$

① voltage:- $v = L\frac{di}{dt}$

② current $i = \frac{1}{L}\int_{t_0}^{t} v(t)\,dt + i(t_0)$

for special case:-

$t_0 = -\infty \rightarrow i(t_0) = 0$

Then $i(t) = \frac{1}{L}\int_{-\infty}^{t} v(t)\,dt = \frac{1}{L}\left[\int_{-\infty}^{0} v(t)\,dt + \int_{0}^{t} v(t)\,dt + i(0)\right]$

power and energy:-

series + parallel are like resistors

$\rightarrow p = vi = \left(L\frac{di}{dt}\right) i$

$\rightarrow w = \frac{1}{2} Li^2$

we say under dc conditions, then.

$w_C = \frac{1}{2}Cv^2 \,/\, w_L = \frac{1}{2}Li^2$

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First Order Circuit: a circuit characterized by a first-order differential Equation..

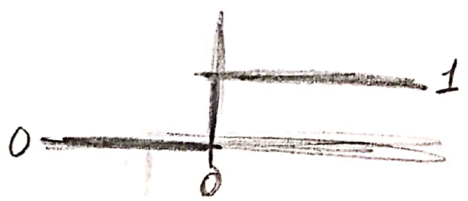
First order circuit $\leftrightarrow$ 1st ODE $\equiv$ RC / RL Circuits.

1st ODE
- → Homo
- → NonHomo (external force / source of power and current).

Unit Step function :- [Singularity functions]

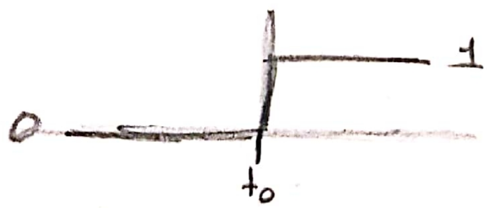
* We used it to model Electric circuits with switches.
* we'll be interested in the case $t > 0$

$$u(t) = \begin{cases} 1, & t > 0 \\ 0, & t < 0 \end{cases}$$

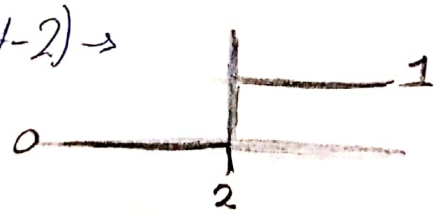


$$u(t) = \begin{cases} 1, & t < 0 \\ 0, & t > 0 \end{cases}$$

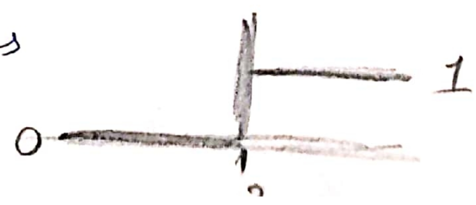
$$u(t - t_0) = \begin{cases} 1, & t > t_0 \\ 0, & t < t_0 \end{cases}$$



$u(t-2) \rightarrow$



$u(t+2) \rightarrow$



Source-free RC → Circuit

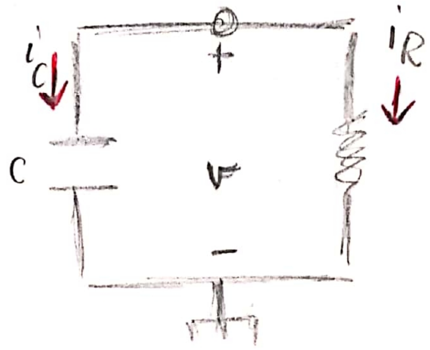
Objective: Determine circuit response.

starting from the initially charged capacitor.

→ $v(0) = V_0$

→ $w(0) = \frac{1}{2} C(V_0)^2$

v cannot change suddenly, nothing restricts i to do so



After diconnecting DC source:-

circuit response:-

① $v(t) = V_0 e^{-t/RC}$ → $\boxed{v(t) = V_0 e^{-t/\tau}}$

→ for which $RC = \tau$ (time constant).

Notes:-

→ response is only due to the initial energy stored and the circuit characterstics, with no external excitations. (Natural response)

time constant:- the time required for the response to decay to a factor of $1/e$ or 36.8 percent of its initial value.

② $i_R(t) = \frac{v(t)}{R} = \frac{V_0}{R} e^{-t/\tau}$ } resistor response

Note that R_{eq} voltage is the same equation above

③ $P_R(t) = v i_R = \frac{V_0^2}{R} e^{-2t/\tau}$

④ $W_R(t) = \frac{1}{2} C V_0^2 (1 - e^{-2t/\tau})$

Notes:-

① it takes 5τ for the circuit to reach its final state, or steady state, when no changes takeplace with time.

② But at any constant time small or large the circuit reaches the steady state at 5τ

③ The smaller τ, the more rapidly voltage decrease (faster response), and vice versa

---

Target:-

→ get $V_C(t)$ so you can find i_C, V_R, i_R

keys:-

→ initial voltage across C is $v(0) = V_0$

→ time constant τ

. . . RL circuit

Source-free RL → circuit

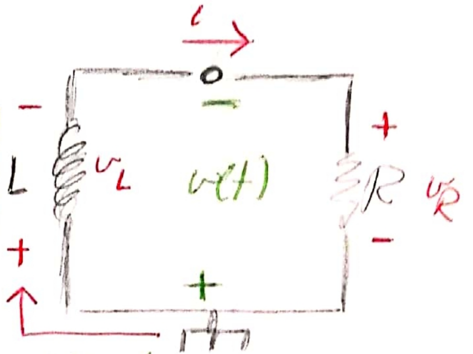
Objective: Determine circuit response.

starting from the intially have a current.

→ $i(0) = I_0$

→ $w(0) = \frac{1}{2} L I_0^2$

i cannot change suddenly, nothing restricts v to do so



we always assume that i(t) enters through positive terminal of the inductor.

After disconnecting DC source:-

circuit response:-

① $i(t) = I_0 e^{-Rt/L}$ ⇒ $i(t) = I_0 e^{-t/\tau}$ for which $\tau = \frac{L}{R}$ (time constant)

Response of R_{eq}, Note that the current is the same above.

② $v_R(t) = iR = I_0 R e^{-t/\tau}$

but $v(t) = -I_0 R e^{-t/\tau}$

③ $P_R(t) = v_R i = I_0^2 R e^{-2t/\tau}$

④ $w_R(t) = \frac{1}{2} L I_0^2 (1 - e^{-2t/\tau})$

Notes:-

① The smaller the τ, the faster the rate of decay of response.

② At any rate, the response decays to less than 1 percent of its initial value after 5τ.

Note that $(v_L = -v_R)$ for same level RL circuit $\left(v_L(t) = -L\frac{di}{dt}\right)$ different directions of polarity + current

Target:-

→ get $i_L(t)$ so you can find (v_L, v_R, i_R)

keys:-

→ initial current through L is $i(0) = i_0$

→ time constant τ.

Step - Response of RC circuit

Note:- the step response of a circuit is its behavior when the excitation is the step function, which may be a voltage or a current source.

Non- Homo geneous :-

remember:

v(t) must be continuous because. capacitor will resist any. abrubt change in its voltage.

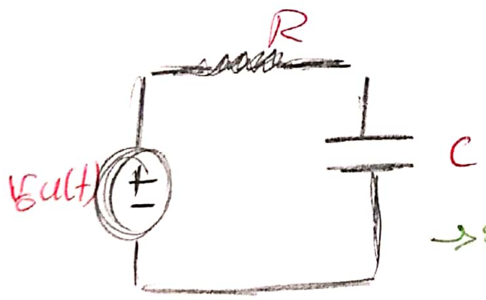
21 April

min 35

In order to analyze step response RC circuits, you need to:-

1. find v_0 (t<0) — v of capacitor
2. find $v(\infty)$ (t>0)

$v(\infty)$ is v of capacitor after t>0

3. 

find $\tau = RC$

→ standard shape.

such that $= \begin{cases} v_0 , & t<0 \\ (v(0) - v(\infty))\, e^{-t/RC} + v(\infty) , & t>0 \end{cases}$

Step-Response of RL circuit

Non-Homogeneous.

remember:-

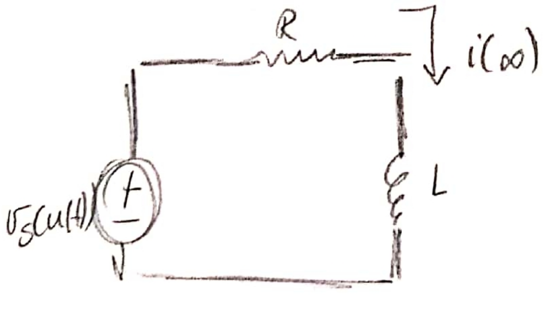
i(t) must be continuous, because inductor will resist any abrubt change in its current.

In order to analyze step response RL circuits, you need to:-

1. find $i(0)$ / $t<0$

2. find $i(\infty)$ / $t>0$

3. find $\tau = \frac{L}{R}$



such that $= \begin{cases} i(0), & t<0 \\ i(\infty) + [i(0) - i(\infty)]e^{-t/\tau} \end{cases}$