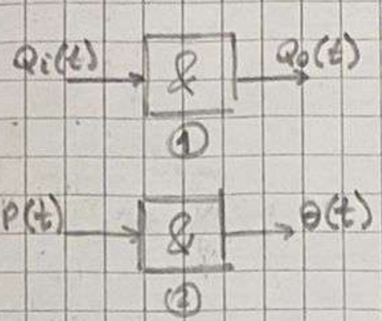
CONSIGNA INTEGRADORA #A



$Q_i(t) = 2 \cdot u(t)$

$P(t) = 6\,[p(t) - p(t-20)]$

$\theta_{AMB}(t) = 20\,°C$

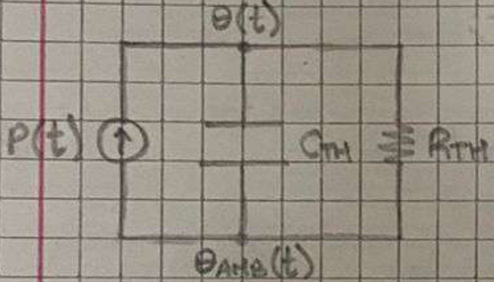
$P_{ATM} = 0\ N/m^2$

$C_{TH} = 2\ Ws/°C$

$R_{TH} = 0{,}5\ °C/W$

$C_H = 5\ m^5/N$

$R_H = 0{,}8\ Ns/m^5$



$$P(t) = P_C(t) + P_R(t)$$

$$P(t) = C_{TH} \cdot \frac{d[\theta(t) - \theta_{AMB}(t)]}{dt} + \frac{\theta(t) - \theta_{AMB}(t)}{R_{TH}}$$

$$P(t) = C_{TH} \cdot \dot{\theta}(t) + \frac{\theta(t)}{R_{TH}} - \frac{\theta_{AMB}(t)}{R_{TH}}$$

NORMALIZANDO: $\frac{P(t)}{C_{TH}} = \dot{\theta}(t) + \frac{\theta(t)}{R_{TH}C_{TH}} - \underbrace{\frac{\theta_{AMB}(t)}{R_{TH}C_{TH}}}_{1}$ ⟸ EDO DEL SIST.

EL TÉRMINO 1 ROMPE CON LA LINEALIDAD DE LA EDO, DE MODO QUE SUPONDREMOS $\theta_{AMB} = 0\,°C$ (SE LA SUMAREMOS AL RESULTADO FINAL PARA EVITAR EL PROBLEMA).

$$\dot{\theta}(t) = \frac{P(t)}{C_{TH}} - \frac{\theta(t)}{R_{TH}C_{TH}}$$ ⟸ NUEVA EDO DEL SISTEMA

SI $\theta(t) = \theta_h(t) + \theta_p(t)$, PROPONGO SOL. HOMOGENEA $\theta_h(t) = Ke^{\lambda t}$, $K \neq 0$

$$\frac{d}{dt}(Ke^{\lambda t}) + \frac{Ke^{\lambda t}}{R_{TH}C_{TH}} = 0 \longrightarrow \lambda Ke^{\lambda t} + \frac{Ke^{\lambda t}}{R_{TH}C_{TH}} = 0$$

$$Ke^{\lambda t}\left(\lambda + \frac{1}{R_{TH}C_{TH}}\right) = 0 \longrightarrow \lambda = -\frac{1}{R_{TH}C_{TH}}$$

$$\theta_h(t) = K\cdot e^{-\frac{t}{R_{TH}\cdot C_{TH}}}$$

SI MI SEÑAL DE ENTRADA ES $P(t) = 6\,[\rho(t) - \rho(t-20)]$, MI SOL. PARTICULAR VA A DEPENDER DEL TRAMO EN EL QUE ESTÉ.

PARA $0 < t < 20 \rightarrow P(t) = 6t \Rightarrow$ PROPONGO SOL. PARTICULAR

$$\theta_{P_1}(t) = At + B$$

$$\begin{cases} \dfrac{d}{dt}(At+B) + \dfrac{At+B}{R_{TH}C_{TH}} = \dfrac{6t}{C_{TH}} \rightarrow A + \dfrac{At}{R_{TH}C_{TH}} + \dfrac{B}{R_{TH}C_{TH}} = \dfrac{6t}{C_{TH}} + 0 \\ A + \dfrac{B}{R_{TH}C_{TH}} = 0 \end{cases}$$

$$\frac{A}{R_{TH}\cancel{C_{TH}}} = \frac{6}{\cancel{C_{TH}}} \rightarrow A = 6R_{TH}$$

$$6R_{TH} + \frac{B}{R_{TH}C_{TH}} = 0 \rightarrow B = -6R_{TH}^2\cdot C_{TH}$$

$$\theta_{P_1}(t) = 6\cdot R_{TH}\cdot t - 6\cdot R_{TH}^2\cdot C_{TH}$$

$$\theta_1(t) = K_1 e^{-\frac{t}{R_{TH}C_{TH}}} + 6\cdot R_{TH}\cdot t - 6\cdot R_{TH}^2\cdot C_{TH}$$

COND. INICIAL $\rightarrow t = 0$

$$\theta_1(0) = K_1\cdot e^0 + 0 - 6\cdot R_{TH}^2\cdot C_{TH} = 0 \rightarrow K_1 = 6R_{TH}^2C_{TH}$$

$$\theta_1(t) = 6R_{TH}^2\cdot C_{TH}\cdot e^{-\frac{t}{R_{TH}\cdot C_{TH}}} + 6\cdot R_{TH}\cdot t - 6\cdot R_{TH}^2\cdot C_{TH}$$

PARA $t > 20 \rightarrow P(t) = 120 \Rightarrow$ PROPONGO SOL. PARTICULAR

$$\theta_{P_2}(t) = C$$

$$\overbrace{\frac{d}{dt}(C)}^{=0} + \frac{C}{R_{TH}\cancel{C_{TH}}} = \frac{120}{\cancel{C_{TH}}} \rightarrow C = 120R_{TH}$$

$$\theta_2(t) = K_2\cdot e^{-\frac{t}{R_{TH}\cdot C_{TH}}} + 120R_{TH}$$

PARA $t = 20 \Rightarrow \theta_1(t) = \theta_2(t)$

$$6R_{TH}^2C_{TH}\cdot e^{-\frac{20}{R_{TH}\cdot C_{TH}}} \cancel{+ 6R_{TH}20} - 6R_{TH}^2C_{TH} = K_2\cdot e^{-\frac{20}{R_{TH}\cdot C_{TH}}} \cancel{+ 120R_{TH}}$$

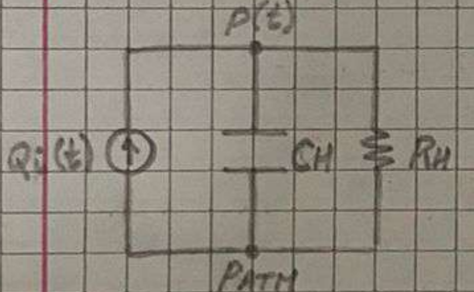
$$K_2 = 6 R_{TH}^2 C_{TH} \cdot e^{\frac{20}{R_{TH}\cdot C_{TH}}}\left(e^{\frac{-20}{R_{TH}\cdot C_{TH}}} - 1\right)$$

$$K_2 = K_1 \cdot e^{\frac{20}{R_{TH}C_{TH}}}\cdot\left(e^{-\frac{20}{R_{TH}\cdot C_{TH}}} - 1\right) = K_1 - K_1\cdot e^{\frac{20}{R_{TH}\cdot C_{TH}}}$$

$$K_2 = K_1\cdot\left(1 - e^{\frac{20}{R_{TH}\cdot C_{TH}}}\right)$$

$$\theta_2(t) = K_1\cdot\left(1-e^{\frac{t}{R_{TH}C_{TH}}}\right)\cdot e^{-\frac{t}{R_{TH}C_{TH}}} + 120 R_{TH}$$

$$\theta(t) = \begin{cases} K_1\cdot e^{-t/\tau} + At + B, & 0 < t < 20 \\ K_2\cdot e^{-t/\tau} + C, & t > 20 \end{cases} + \theta_{AMB}, \quad \tau = R_{TH}C_{TH}$$



$$Q_i(t) = Q_C(t) + Q_R(t)$$

$$Q_i(t) = C_H\cdot\frac{d[p(t)-p_{ATM}]}{dt} + \frac{p(t)-p_{ATM}}{R_H}$$

$$Q_i(t) = C_H\cdot\dot p(t) + \frac{p(t)}{R_H} - \cancel{\frac{p_{ATM}}{R_H}}^{=0}$$

NORMALIZANDO: $$\dot p(t) = \frac{Q_i(t)}{C_H} - \frac{p(t)}{R_H C_H}$$ ← EDO DEL SIST.

SI $p(t) = p_h(t) + p_p(t)$, PROPONGO SOL. HOMOGÉNEA $p_p(t) = Ke^{\lambda t}$, $K \neq 0$

$$\frac{d}{dt}\left(Ke^{\lambda t}\right) + \frac{Ke^{\lambda t}}{R_H\cdot C_H} = 0 \longrightarrow K\lambda e^{\lambda t} + \frac{Ke^{\lambda t}}{R_H C_H} = 0$$

$$Ke^{\lambda t}\left(\lambda + \frac{1}{R_H\cdot C_H}\right) = 0 \longrightarrow \lambda = -\frac{1}{R_H\cdot C_H} \quad \therefore\ p_h(t) = K\cdot e^{-\frac{t}{R_H C_H}}$$

SI MI SEÑAL DE ENTRADA ES $Q_i(t) = 2\cdot u(t)$, LA SOLUCIÓN PARTICULAR DEPENDERÁ DEL TRAMO EN EL QUE ESTÉ.

PARA $t > 0 \rightarrow Q_i(t) = 2 \Rightarrow$ PROPONGO SOL. PARTICULAR $p_p(t) = A$

$$\cancel{\frac{d}{dt}}\overbrace{(A)}^{=0} + \frac{A}{R_H \cancel{C_H}} = \frac{2}{\cancel{C_H}} \rightarrow A = 2R_H$$

$$p_p(t) = 2R_H \therefore p(t) = K \cdot e^{-\frac{t}{R_H C_H}} + 2R_H$$

$CI \rightarrow$ PARA $t = 0$, $Q_i(t) = 0 \searrow K \cdot e^{0} + 2R_H = 0 \rightarrow K = -2R_H$

$$p(t) = (-2R_H) \cdot e^{-\frac{t}{R_H \cdot C_H}} + 2R_H$$

$$p(t) = 2R_H \left(1 - e^{-\frac{t}{R_H \cdot C_H}}\right)$$

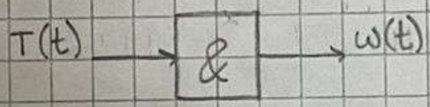
COMO $Q_0(t) = \dfrac{p(t)}{R_H} \Rightarrow Q_0(t) = 2\left(1 - e^{-\frac{t}{R_H \cdot C_H}}\right) \cdot u(t)$

CONSIGNA INTEGRADORA #B

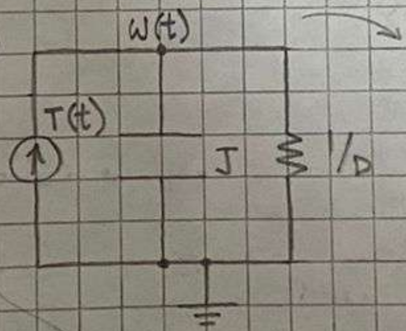
$J = 1 \ \text{Kg}\,\text{m}^2$

$D = 0{,}5 \ \dfrac{\text{Nm seg}}{}$

$K = 2 \ \dfrac{\text{Nm rad}}{\text{rad}}$



a)



$T(t) = J \cdot \dot{\omega}(t) + D\,\omega(t)$

NORMALIZO:

$$\dot{\omega}(t) = \frac{T(t)}{J} - \frac{D}{J}\omega(t)$$

SI $\omega(t) = \omega_p(t) + \omega_h(t)$

PROPONGO SOL. HOMOGENEA

$\omega_h(t) = Ke^{\lambda t}$, $K \neq 0$

$$J \cdot \frac{d}{dt}(Ke^{\lambda t}) + D \cdot Ke^{\lambda t} = 0 \rightarrow JK\lambda e^{\lambda t} + DKe^{\lambda t} = 0$$

$$Ke^{\lambda t}(J\lambda + D) = 0 \rightarrow \lambda = -D/J \therefore \omega_h(t) = Ke^{-D/J \cdot t}$$

CONSIDERO $T(t) = u(t) \rightarrow$ PROPONGO SOL. PARTICULAR $\omega_p(t) = A$

PARA $t > 0$, $u(t) = 1 \Rightarrow J \cdot \cancel{\dfrac{d}{dt}}\overbrace{(A)}^{=0} + D \cdot A = 1 \Rightarrow A = 1/D$

$$\therefore \omega(t) = Ke^{-D/J \cdot t} + 1/D$$

CI $\rightarrow$ PARA $t = 0$, $u(t) = 0$

$$K \cdot e^{0} + 1/D = 0 \rightarrow K = -1/D \therefore \omega(t) = -1/D \cdot e^{-D/J \cdot t} + 1/D$$

$$\omega(t) = A\left(1 - e^{-t/\tau}\right) \cdot u(t), \quad \tau = J/D$$

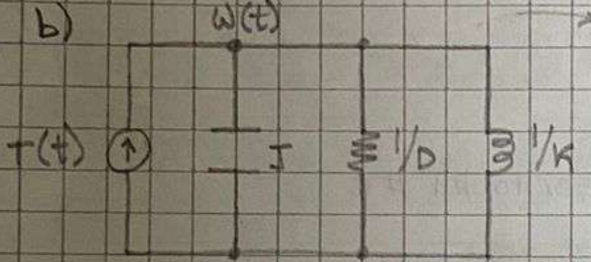
RESPUESTA INDICIAL

$$y(t)\Big|_{T(t)=u(t)} = g(t) = A\left(1 - e^{-t/\tau}\right) \cdot u(t)$$

RESPUESTA IMPULSIONAL

$$h(t) = \frac{d}{dt}(g(t)) = A \cdot 1/\tau \cdot e^{-t/\tau} \cdot u(t)$$

b)



$$T(t) = J \cdot \dot{\omega}(t) + D\omega(t) + K \cdot \int_{-\infty}^{t} \omega(\tau)\, d\tau$$

SI $\omega(t) = \dot{\theta}(t)$

$$T(t) = J \cdot \ddot{\theta}(t) + D \cdot \dot{\theta}(t) + K\theta(t)$$

SI $\theta(t) = \theta_p(t) + \theta_h(t)$

PROPONGO SOL. HOMOGENEA

$$\theta_h(t) = K e^{\lambda t}, \quad K \neq 0$$

$$J \cdot \frac{d^2}{dt^2}(K e^{\lambda t}) + D \cdot \frac{d}{dt}(K \cdot e^{\lambda t}) + K \cdot K \cdot e^{\lambda t} = 0$$

$$J \cdot K \cdot \lambda^2 \cdot e^{\lambda t} + D \cdot K \cdot \lambda \cdot e^{\lambda t} + K \cdot K \cdot e^{\lambda t} = 0$$

$$K \cdot e^{\lambda t}(J\lambda^2 + D\lambda + K) = 0 \rightarrow J\lambda^2 + D\lambda + K = 0$$

$$\lambda_1, \lambda_2 = \frac{-D \pm \sqrt{D^2 - 4 \cdot J \cdot K}}{2J}$$

$\rightarrow \lambda_1 \neq \lambda_2 \in \mathbb{R} \,/\, D^2 - 4JK > 0$
$\rightarrow \lambda_1 = \lambda_2 \in \mathbb{R} \,/\, D^2 - 4JK = 0$
$\rightarrow \lambda_1, \lambda_2 \in \mathbb{C} \,/\, D^2 - 4JK < 0$ ⊗

PARA $J = 1 \wedge D = 0{,}5 \wedge K = 2$

POR MATLAB $\rightarrow \lambda_1 = \overbrace{-0{,}25}^{a} + \overbrace{1{,}3919}^{b} i$
$\rightarrow \lambda_2 = -0{,}25 - 1{,}3919 i$

$$\theta_h(t) = e^{at} \cdot [K_1 \cdot \cos(bt) + K_2 \cdot \operatorname{sen}(bt)]$$

CONSIDERO $T(t) = u(t)$ / PARA $t>0$, $u(t)=1$

PROPONGO SOL. PARTICULAR $\theta_p(t) = B$

$$J \cdot \underbrace{\cancel{\frac{d^2}{dt^2}(B)}}_{=0} + D \cdot \underbrace{\cancel{\frac{d}{dt}(B)}}_{=0} + K \cdot B = 1 \Rightarrow B = 1/K$$

$$\theta(t) = e^{at} \cdot [K_1 \cdot \cos(bt) + K_2 \cdot \operatorname{sen}(bt)] + 1/K$$

$$C.I. \begin{cases} \theta(0) = 0 \\ \dot{\theta}(0) = 0 \end{cases}$$

$$\theta(0) = e^0 \cdot [K_1 \cdot \cos(0) + \underbrace{\cancel{K_2 \operatorname{sen}(0)}}_{=0}] + 1/K = 0 \rightarrow K_1 = -1/K$$

$$\dot{\theta}(t) = a e^{at} \cdot [K_1 \cdot \cos(bt) + K_2 \cdot \operatorname{sen}(bt)] + e^{at} \cdot [-K_1 \cdot b \cdot \operatorname{sen}(bt) + K_2 \cdot b \cdot \cos(bt)]$$

$$\dot{\theta}(0) = a \cdot e^0 \cdot [K_1 \cdot \cos(0) + \underbrace{\cancel{K_2 \cdot \operatorname{sen}(0)}}_{=0}] + e^0 \cdot [\underbrace{\cancel{-K_1 \cdot b \cdot \operatorname{sen}(0)}}_{=0} + K_2 \cdot b \cdot \cos(0)] = 0$$

$$= a \cdot K_1 + K_2 \cdot b = 0 \rightarrow K_2 = -a/b \cdot K_1$$

$$\theta(t) = e^{at} \cdot [K_1 \cdot \cos(bt) - a/b \cdot K_1 \cdot \operatorname{sen}(bt)] + 1/K$$

$$\theta(t) = \left\{ e^{at} \cdot [-B \cdot \cos(bt) + a/b \cdot B \cdot \operatorname{sen}(bt)] + B \right\} \cdot u(t)$$

RESPUESTA INDICIAL

$$y(t)\Big|_{T(t)=u(t)} = g(t) = \left\{ e^{at} \cdot [-B \cdot \cos(bt) + a/b \cdot B \cdot \operatorname{sen}(bt)] + B \right\} \cdot u(t)$$

RESPUESTA IMPULSIONAL

$$h(t) = \frac{d}{dt}(g(t)) = a e^{at} \cdot \left\{ [-B \cdot \cos(bt) + a/b \cdot B \cdot \operatorname{sen}(bt)] \right\} +$$

$$e^{at} \cdot \left\{ [B \cdot b \cdot \operatorname{sen}(bt) + a/\cancel{b} \cdot B \cdot \cancel{b} \cdot \cos(bt)] \right\} \cdot u(t)$$

$$h(t) = [\cancel{-a \cdot B \cdot e^{at} \cdot \cos(bt)} + a^2B/b \cdot e^{at} \cdot \operatorname{sen}(bt) + e^{at} \cdot B \cdot b \cdot \operatorname{sen}(bt) + \cancel{a \cdot B \cdot e^{at} \cdot \cos(bt)}]\, u(t)$$

$$h(t) = [e^{at} \cdot \operatorname{sen}(bt) \cdot B \cdot (a^2/b + b)]\, u(t)$$

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TareaAIntegradora_Clase6

Sanchez Sosa

Consigna de la clase #A INTEGRADORA Obtener las ecuaciones que modelan el siguiente termotanque eléctrico (termicas e hidraulicas por separado y calcular cada una de las respuestas del mismo para las excitaciones Qi=2*u(t) y P(t)=6*[p(t)-p(t-20)]. Verificar ambos resultados en MatLab.

```
clc;
clear;
close all;
```

Parte termica

```
dt_t=0.001;
t=0:dt_t:40;
CI=(0);
Rth=0.5;
Cth=2;
TITA_AMB=20;
% Senal de entrada
x0_in=@(t) 6*(rampa(t)-rampa(t-20));
pot=x0_in(t);

% Constantes hallada a partir de la sol.homogenea
tao_t=Rth*Cth;
lambda_t=-1/tao_t;

% Constantes halladas a partir de la sol. particular
% para 0<t<20
A=6*Rth;
B=-6*Rth^2*Cth;
% para t>20
C=20*A;

% Constantes halladas a partir de las CI
% para 0<t<20
k1=6*Rth^2*Cth;
% para t>20
k2=k1*(1-exp(TITA_AMB/tao_t));

% Solucion numerica
[t_ode, Y1] = ode45(@(t,y) first_order_function_T(t,y,x0_in), t, CI);
Y_numerica_T=Y1+TITA_AMB; % Sumo los 20°C de temperatura ambiente.
```

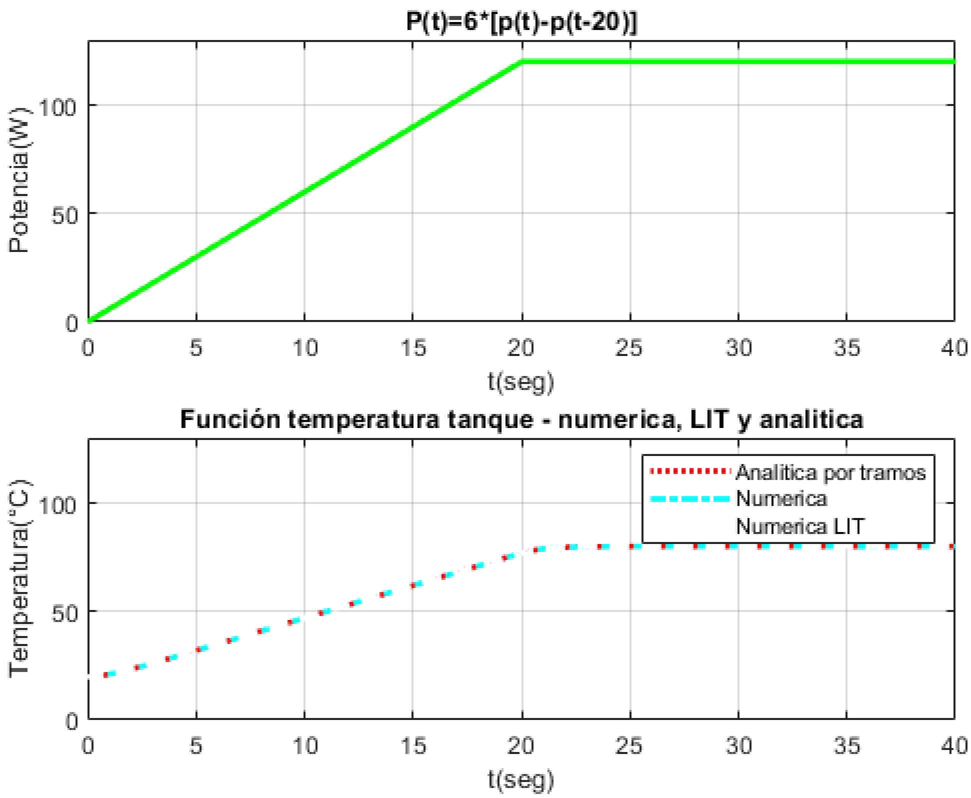
```
% Solucion analitica
tita_tramo1=(k1*exp(-t/tao_t)+A*t+B).*(escalon(t)-escalon(t-20)); %
 0<t<20
tita_tramo2=(k2*exp(-t/tao_t)+C).*escalon(t-20); % t>20
% De esta forma le informo a Matlab que la funcion a evaluar es por
 tramos
Y_analitica_T=tita_tramo1+tita_tramo2+TITA_AMB;

% Senal/es de entrada
x1_in=@(t) 6*rampa(t);
x2_in=@(t) -6*rampa(t-20);
xt_in=x1_in(t)+x2_in(t);
% Con estas 3 funciones, evaluo si es LIT
[t_ode1, Y2] = ode45(@(t,y) first_order_function_T(t,y,x1_in), t, CI);
[t_ode2, Y3] = ode45(@(t,y) first_order_function_T(t,y,x2_in), t, CI);
Ylit=Y2+Y3+20;

% Graficos
figure;

subplot(211)
plot(t,pot,'g','linewidth',2)
xlabel('t(seg)')
ylabel('Potencia(W)')
grid on
axis tight
title('P(t)=6*[p(t)-p(t-20)]')
ylim([0 130])

subplot(212)
plot(t,Y_analitica_T,'r:',t_ode,Y_numerica_T,'c-.',t_ode,Ylit,'w--','linewidth',2)
xlabel('t(seg)')
ylabel('Temperatura(°C)')
grid on
axis tight
legend('Analitica por tramos','Numerica','Numerica LIT')
title ('Función temperatura tanque - numerica, LIT y analitica')
ylim([0 130])
```



Parte hidraulica

```
dt_h=0.001;
t=-5:dt_h:35;
CI=(0);
Rh=0.8;
Ch=5;
P_ATM=0;
% Senal de entrada
x_in=@(t) 2*escalon(t);
Qi=x_in(t);

% Constante hallada a partir de la sol.homogenea
tao_h=Rh*Ch;
lambda_h=-1/tao_h;

% Constantes halladas a partir de la sol. particular
D=2*Rh;

% Constantes halladas a partir de las CI
k=-D; % k=2*Rh

% Solucion numerica
[t_ode, Y] = ode45(@(t,y) first_order_function_H(t,y,x_in), t, CI);
Y_numerica_H=(1/Rh)*Y+P_ATM; % Sumo los 0°C de presion atmosferica.
```

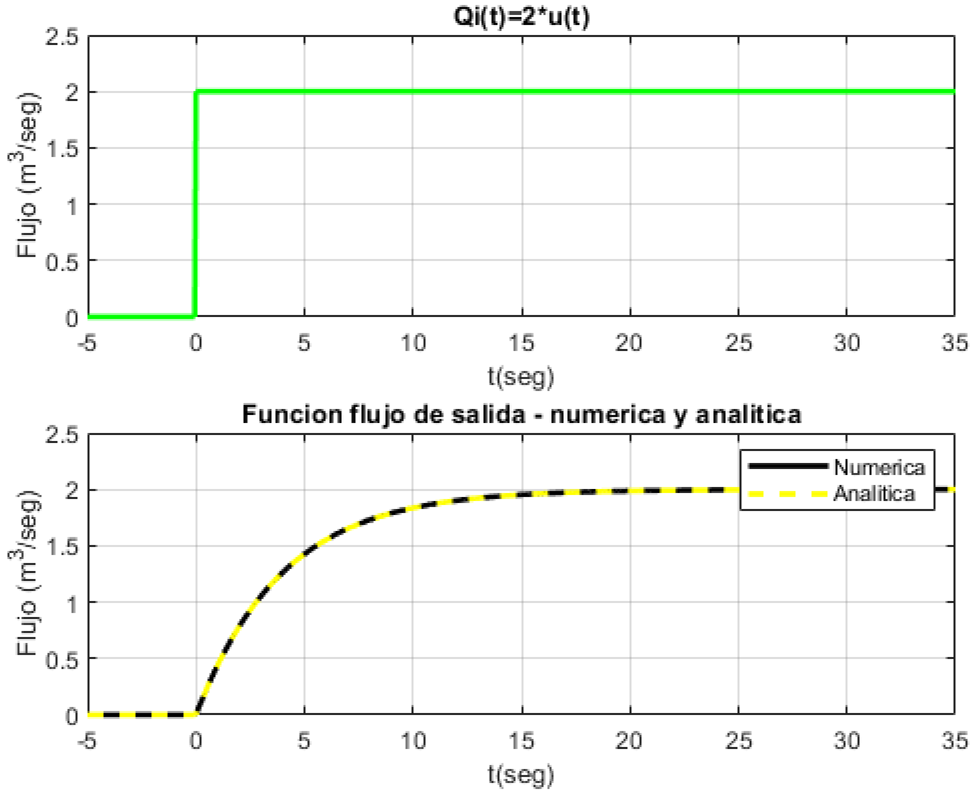
```
% Solucion analitica
p=k*exp(-t/tao_h)+D;
Qo=(p/Rh).*escalon(t);
Y_analitica_H=Qo+P_ATM;

% Graficos
figure;

subplot(211)
plot(t,Qi,'g','linewidth',2)
grid on
axis tight
xlabel('t(seg)')
ylabel('Flujo (m^3/seg)')
title('Qi(t)=2*u(t)')
ylim([0 2.5])

subplot(212)
plot(t_ode,Y_numerica_H,'k',t,Y_analitica_H,'y--','linewidth',2)
grid on
axis tight
xlabel('t(seg)')
ylabel('Flujo (m^3/seg)')
legend ('Numerica','Analitica')
title ('Funcion flujo de salida - numerica y analitica')
ylim([0 2.5])

% 1. El flujo de salida Qo(t) se estabiliza en 2 m^3/seg.
% 2. La temperatura del tanque alcanza un valor maximo de 80°C. Es
 decir,
% está 60°C por encima de la  temperatura ambiente (20°C).
```



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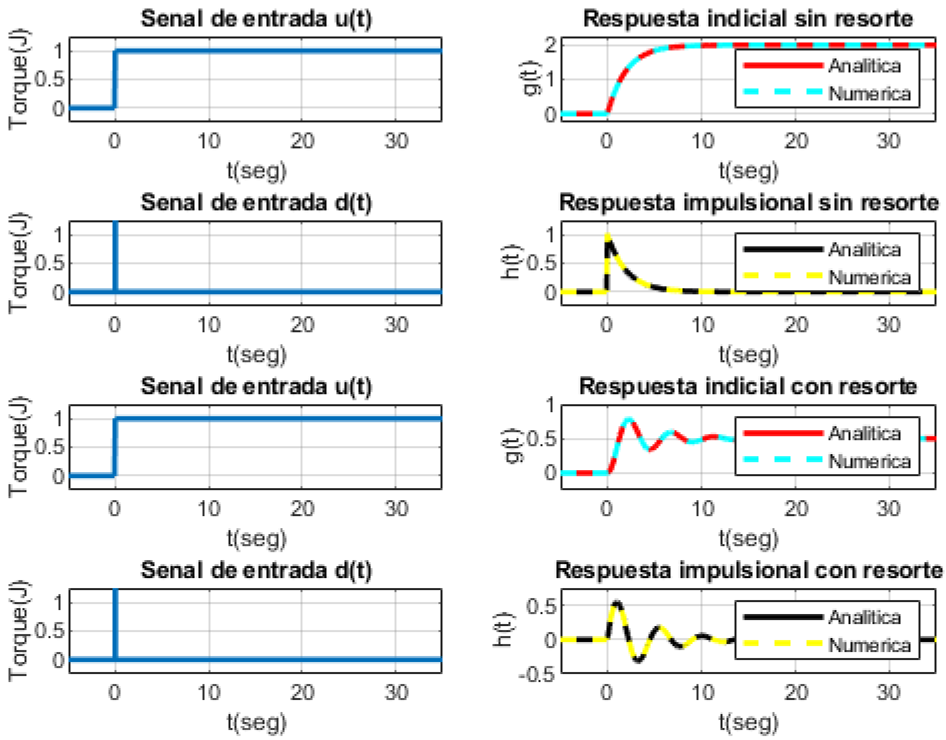
TareaBIntegradora_Clase6_Punto1

Sanchez Sosa

```
% 1. Obtener las respuestas indicial (al escalón, g(t)) e impulsional
 (al
% impulso,h(t)) correspondientes al siguiente sistema físico, al que
 se le
% aplica un torque T(t). Considerar a) el resorte K desconectado
% (respuesta omega(t)) y b) el resorte K conectado (respuesta
 tita(t)).
% Utilizar MatLab para verificar numéricamente el resultado.

clc;
clear;
close all;

dt=0.001;
t=-5:dt:35;
CI_SR=(0); % Condiciones iniciales para el esquema SIN RESORTE
CI_CR=([0 0]); % Condiciones iniciales para el esquema CON RESORTE
J=1;
D=0.5;
K=2;

% Constantes hallada a partir de la sol.homogenea
tao=J/D;
lambda=-1/tao;

% Constantes halladas a partir de la sol. particular
A=1/D;

% Constantes halladas a partir de las CI
k=-A;

% Senal de entrada u(t)
u_in=@(t) escalon(t);
Tor_u=u_in(t);

% Senal de entrada d(t)
d_in=@(t) delta(t);
Tor_d=d_in(t);

% Solucion analitica (SIN RESORTE=SR)
ganalit_SR=(A*(1-exp(-t/tao))).*Tor_u; % R. indicial
hanalit_SR=((A/tao)*exp(-t/tao)).*Tor_u;% R. impulsional

% Solucion numerica (SIN RESORTE=SR)
[t_ode1, gnum_SR] = ode45(@(t,y) first_order_function_M(t,y,u_in), t,
 CI_SR);
dtnum=t(2)-t(1); %dt=dtnum
hnum_SR=diff(gnum_SR/dtnum); %h(t)=d(g(t))/dt <-- derivada
```

```
% Constantes hallada a partir de la sol.homogenea
a=-1/4;
b=1.3919;
lambda_1=a+b*1i;
lambda_2=a-b*1i;

% Constantes halladas a partir de la sol. particular
B=1/K;

% Constantes halladas a partir de las CI
k1=-B; % k1=1/K
k2=(-a/b)*k1;

% Solucion analitica (CON RESORTE=CR)
ganalit_CR=(exp(a*t).*(k1*cos(b*t)+k2*sin(b*t))+B).*Tor_u; % R.
 indicial
hanalit_CR=(((a^2/b)+b)*B*exp(a*t).*sin(b*t)).*Tor_u; % R. impulsional

% Solucion numerica (CON RESORTE=CR)
[t_ode2, gnum] = ode45(@(t,y) second_order_function_M(t,y,u_in), t,
 CI_CR);
gnum_CR=gnum(:,1); % De esta forma me quedo con la primer columna, que
 es
% mi funcion g(t).
dtnum=t(2)-t(1); %dt=dtnum
hnum_CR=diff(gnum_CR/dtnum); %h(t)=d(g(t))/dt <-- derivada

% Graficos (SIN RESORTE)
figure;

subplot(421)
plot(t,Tor_u,'linewidth',2)
grid on
axis tight
xlabel('t(seg)')
ylabel('Torque(J)')
title('Senal de entrada u(t)')
ylim([-0.25 1.25])

subplot(422)
plot(t,ganalit_SR,'r',t_ode1,gnum_SR,'c--','linewidth',2)
grid on
axis tight
xlabel('t(seg)')
ylabel('g(t)')
legend('Analitica','Numerica')
title('Respuesta indicial sin resorte')
ylim([-0.25 2.25])

subplot(423)
plot(t,Tor_d,'linewidth',2)
grid on
axis tight
```

```
xlabel('t(seg)')
ylabel('Torque(J)')
title('Senal de entrada d(t)')
ylim([-0.25 1.25])

subplot(424)
plot(t,hanalit_SR,'k',t(1:end-1),hnum_SR,'y--','linewidth',2)
grid on
axis tight
xlabel('t(seg)')
ylabel('h(t)')
legend('Analitica','Numerica')
title('Respuesta impulsional sin resorte')
ylim([-0.25 1.25])

% Graficos (CON RESORTE)

subplot(425)
plot(t,Tor_u,'linewidth',2)
grid on
axis tight
xlabel('t(seg)')
ylabel('Torque(J)')
title('Senal de entrada u(t)')
ylim([-0.25 1.25])

subplot(426)
plot(t,ganalit_CR,'r',t_ode1,gnum_CR,'c--','linewidth',2)
grid on
axis tight
xlabel('t(seg)')
ylabel('g(t)')
legend('Analitica','Numerica')
title('Respuesta indicial con resorte')
ylim([-0.25 1])

subplot(427)
plot(t,Tor_d,'linewidth',2)
grid on
axis tight
xlabel('t(seg)')
ylabel('Torque(J)')
title('Senal de entrada d(t)')
ylim([-0.25 1.25])

subplot(428)
plot(t,hanalit_CR,'k',t_ode2(1:end-1),hnum_CR,'y--','linewidth',2)
grid on
axis tight
xlabel('t(seg)')
ylabel('h(t)')
legend('Analitica','Numerica')
title('Respuesta impulsional con resorte')
ylim([-0.5 0.75])
```



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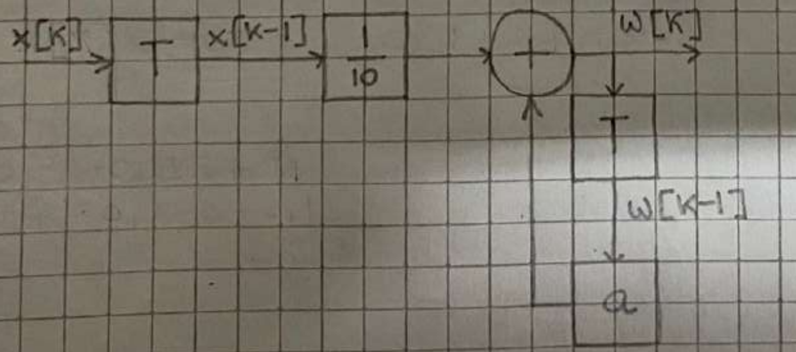
② $T(t) = J \cdot \dot{\omega}(t) + D \cdot \omega(t) \rightarrow T(t) = \dot{\omega}(t) + 0{,}5 \cdot \omega(t)$

CONSIDERO $T(t) = u(t)$ / PARA $t > 0$, $u(t) = 1 \;\therefore\; \dot{\omega}(t) + 0{,}5 \cdot \omega(t) = 1$

$\dot{\omega}(t) + 0{,}5\,\omega(t) = 1 \rightarrow \omega[m+1] - a \cdot \omega[m] = Ts \cdot x[m]$, $a = 1 - 0{,}5 \cdot Ts$

SI $K = m+1 \rightarrow \omega[K] = a \cdot \omega[K-1] + Ts \cdot x[K-1]$, $x[K] = u[K]$

K	m	$t = KT_s$	$\omega(mT_s)_A$	$x[K-1]$	$\omega[K-1]$	$\omega[K]_N$	Error
0	-1	0	0	CI 0	0	0	0
1	0	0,1	0,0975	1	0	0,1	0,0025
2	1	0,2	0,1903	1	0,1	0,195	0,0047
3	2	0,3	0,2786	1	0,195	0,2853	0,0067
4	3	0,4	0,3625	1	0,2853	0,3710	0,0085
5	4	0,5	0,4424	1	0,3710	0,4525	0,0101
6	5	0,6	0,5184	1	0,4525	0,5299	0,0115



DIAG. EN BLOQUES