# VIBRATION IN A CABLE HOIST.

APPROVED
By COHONGTRAN at 10:24 am, Dec 04, 2008

by **CO.H . TRAN** - *NCU - HUI , HCMC Vietnam -*

*mailto:coth123@math.com cohtran@math.com*


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** ***Abstract :*** We consider the non-linear random vibration model described by the system of differential equations .
The solution can be found by using the inverse Laplace transformation .

** ***Subjects:*** Vibration Mechanics , The Differential equations .

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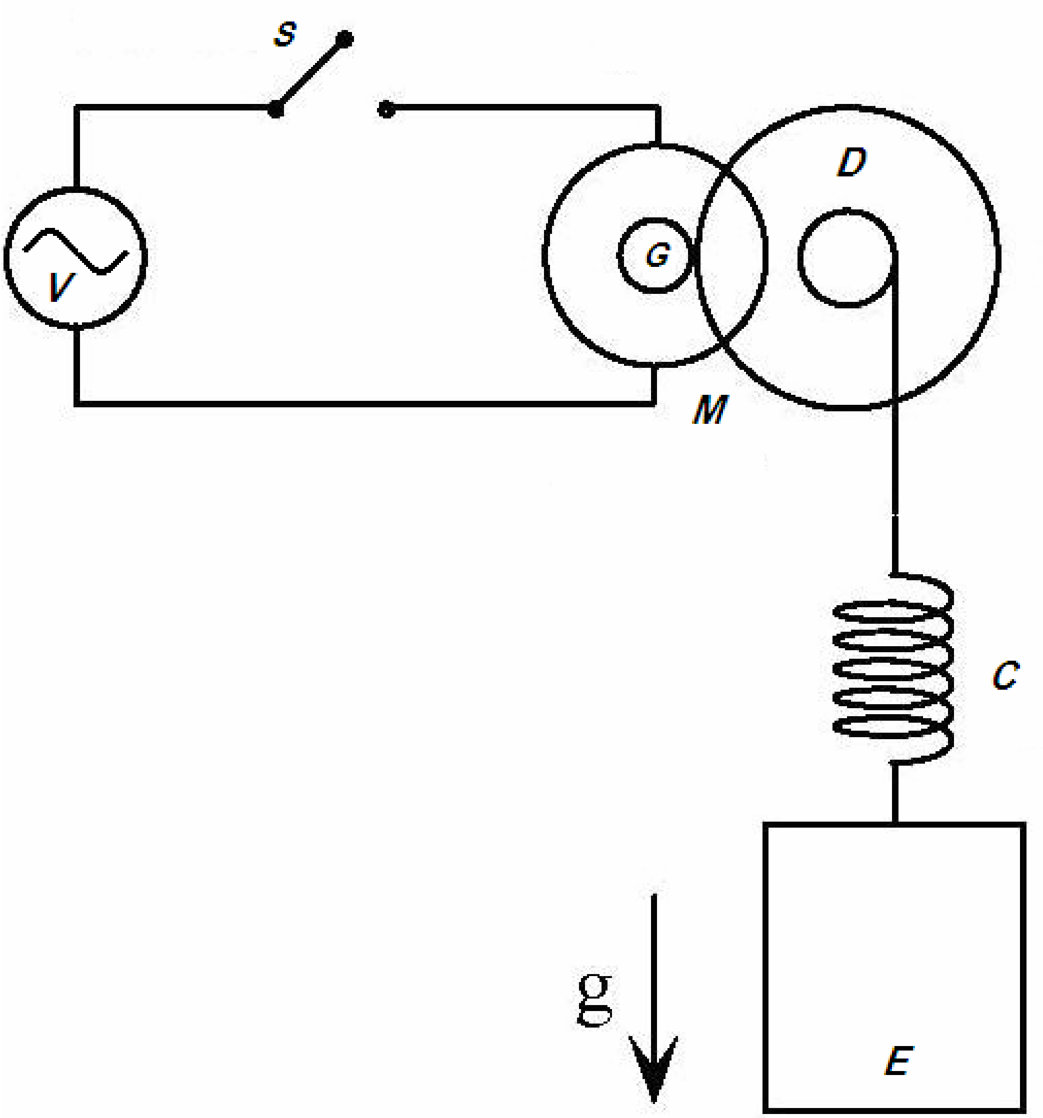
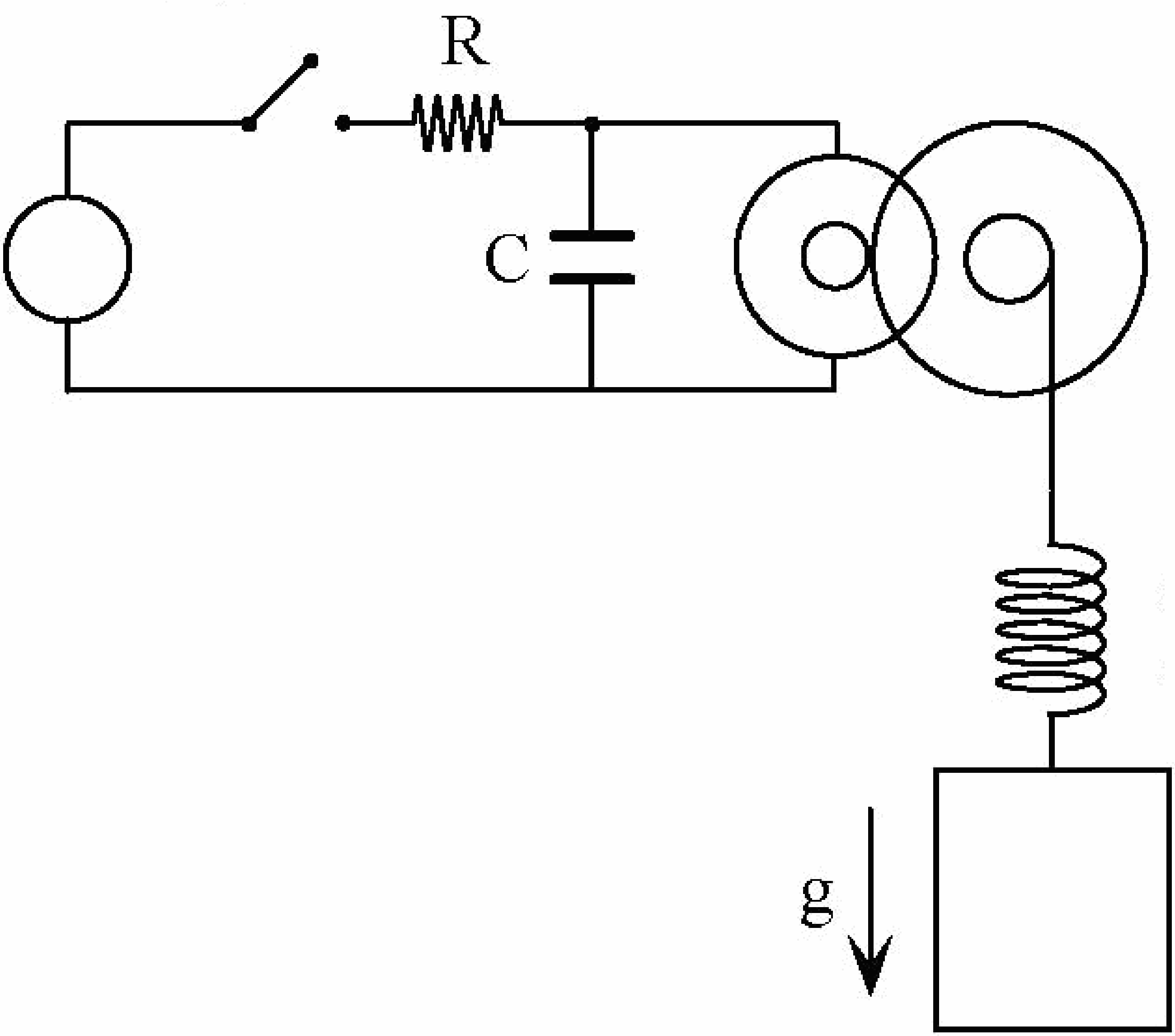
NOTE:
*This worksheet demonstrates Maple's capabilities in the design and finding the numerical solution of the non-linear vibration system .*


## 1. Model Definition .

Voltage supply : V
Switch : S
Geartrain : G
Motor : M .
Drum : D
Cable : C
Elevator cage : E
( Fig.1)
The cage E is hoisted by cable C wound over a drum D driven through a gear-set G by an electric motor M .
Assume that :

* the cable C  has low internal friction .
* the variation of weight supported with length change may be ignored
* weight is concentrated  in the cage E
* variation of cable C with length change may be ignored
* the  cable C  internal damping may be neglected  .
* drum D  and gear G  inertia may be ignored .
* DC electric motor with constant magnetic field .
* motor armature resistance & inductance may be neglected
* relay resistance may be neglected
* internal resistance of the voltage supply may be neglected .






( Fig.1 )
( Fig.2)

## 2 . The system of  differential equations :

$$\begin{cases} m_E \dfrac{d^2 x_E}{dt^2} = k_C (x_l - x_E) - m_E . g \\ \omega_D = n_G . \omega_M \\ \omega_M = \dfrac{e_M}{K_M} \ ; \ K_M : \text{ coeffient of motor tran sduction .} \\ \dfrac{dx_l}{dt} = r_D . \omega_D \end{cases}$$

$e1 := m_E \left( \dfrac{d^2}{dt^2} x_E(t) \right) = k_C \left( x_l(t) - x_E(t) \right) + m_E \, g \qquad e2 := \omega_M(t) = \dfrac{e_M(t)}{K_M} \qquad e3 := \dfrac{d}{dt} x_l(t) = r_D \, \omega_D$

$f2 := \omega_D = n_G \, \omega_M \quad \omega_D := n_G \, \omega_M$

$$e1 := m_E \left(\frac{d^2}{dt^2} x_E(t)\right) = k_C\,(x_l(t) - x_E(t)) + m_E\, g \qquad e2 := \omega_M(t) = \frac{e_M(t)}{K_M} \qquad e3 := \frac{d}{dt} x_l(t) = r_D\, n_G(t)\, \omega_M(t)$$

$$E1 := -m_E\,(\mathrm{D}(x_E)(0) + s\, x_E(0)) + m_E\, s^2\, \mathrm{laplace}(x_E(t), t, s) =$$

$$k_C\, \mathrm{laplace}(x_l(t), t, s) - k_C\, \mathrm{laplace}(x_E(t), t, s) + \frac{m_E\, g}{s}$$

$$E2 := \omega_M(t) = \frac{e_M(t)}{K_M}$$

$$E3 := s\, \mathrm{laplace}(x_l(t), t, s) - x_l(0) = r_D\, \mathrm{laplace}(n_G(t)\, \omega_M(t), t, s)$$

$$x_E(0) := 0 \quad x_l(0) := 0 \quad \mathrm{D}(x_E)(0) := 0$$

$$E1 := m_E\, s^2\, \mathrm{laplace}(x_E(t), t, s) = k_C\, \mathrm{laplace}(x_l(t), t, s) - k_C\, \mathrm{laplace}(x_E(t), t, s) + \frac{m_E\, g}{s}$$

$$E2 := \mathrm{laplace}(\omega_M(t), t, s) = \frac{\mathrm{laplace}(e_M(t), t, s)}{K_M}$$

$$E3 := s\, \mathrm{laplace}(x_l(t), t, s) = r_D\, \mathrm{laplace}(n_G(t)\, \omega_M(t), t, s)$$

$$\frac{\mathrm{laplace}(x_l(t), t, s)}{\mathrm{laplace}(e_M(t), t, s)} = \frac{r_D\, \mathrm{laplace}(n_G(t)\, \omega_M(t), t, s)}{s\, \mathrm{laplace}(e_M(t), t, s)}$$

$$\frac{\mathrm{laplace}(x_l(t), t, s)}{\mathrm{laplace}(e_M(t), t, s)} = \frac{r_D\, \mathrm{laplace}(n_G(t)\, \omega_M(t), t, s)}{s\, K_M\, \mathrm{laplace}(\omega_M(t), t, s)}$$

$$eq1 := (m_E\, s^2 + k_C)\, x_E = k_C\, x_l \qquad eq2 := s\, x_l = \frac{r_D\, n_G\, e_M}{K_M} \qquad eq3 := \frac{x_E}{e_M} = \frac{r_D\, n_G\, k_C}{K_M\, m_E\, s \left(s^2 + \frac{k_C}{m_E}\right)}$$

$$e_E := 0.05 \quad k_C := 1.5 \quad K_M := 3.2 \quad m_E := 100 \quad r_D := 2.1 \quad n_G := 4$$

$$\left\{ s = s,\ x_E = \frac{7.875000000\, e_M}{s\,(200.\, s^2 + 3.)},\ x_l = \frac{2.625000000\, e_M}{s} \right\}$$

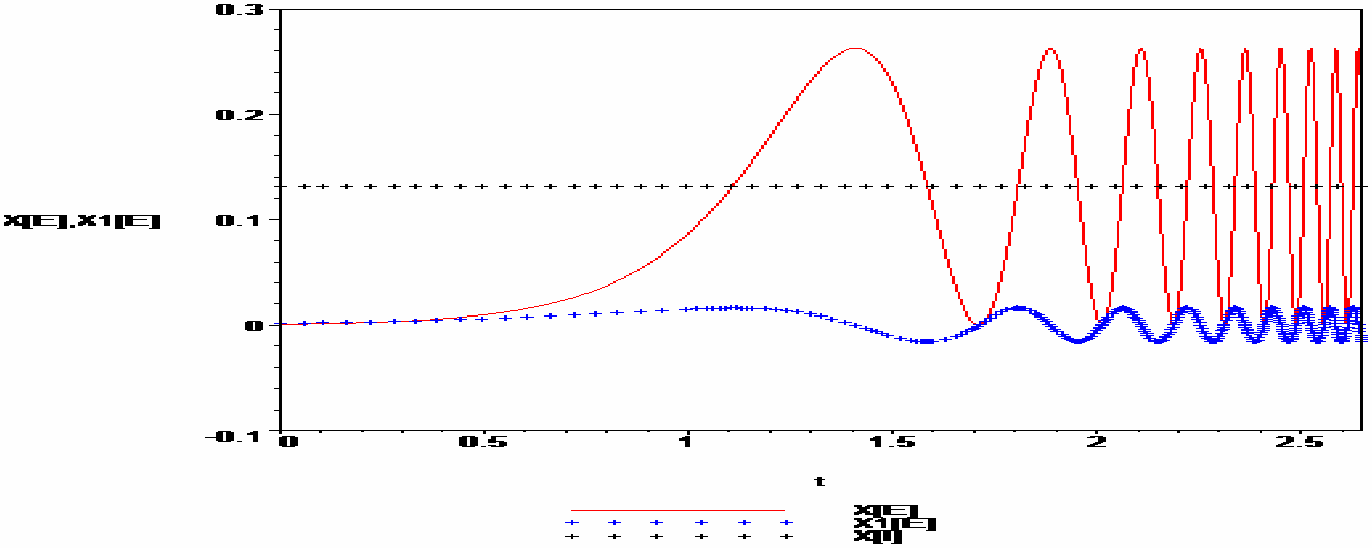
$$X0_E := -0.1312500000\, \cos(0.1224744872\, t) + 0.1312500000$$

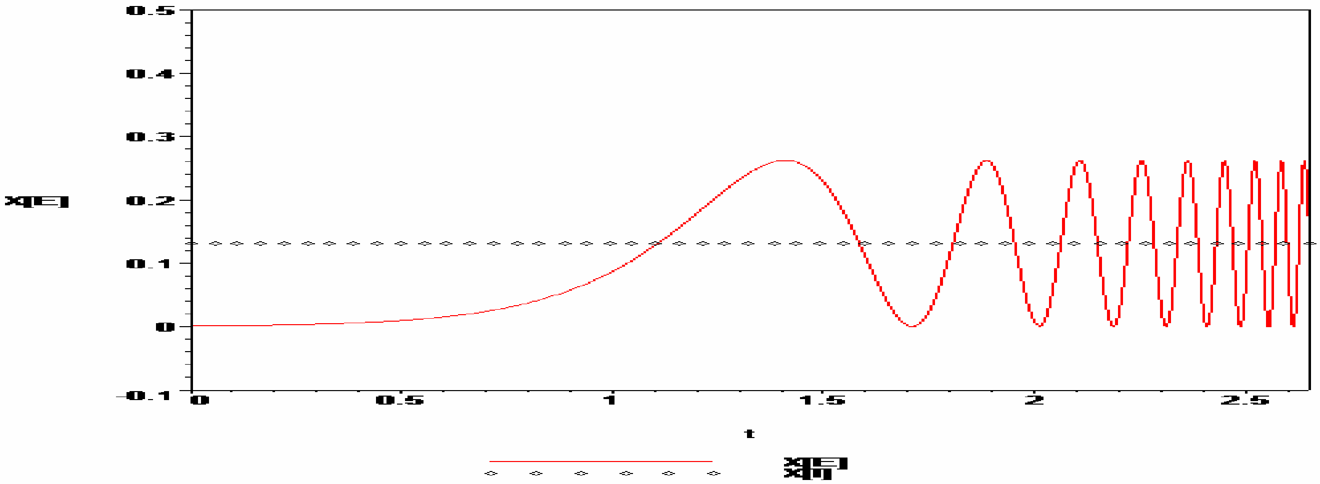
$$X_E := -0.1312500000\, \cos(0.1224744872\, t) + 0.1312500000$$

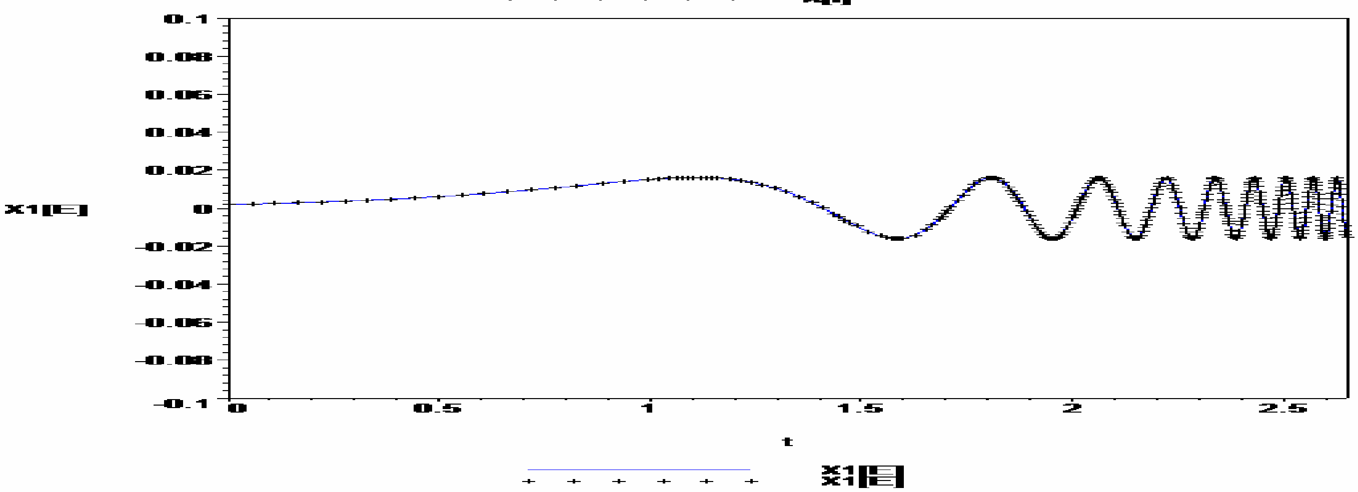
$$X_E := -0.1312500000\, \cos(0.1224744872\, 10^w) + 0.1312500000$$

$$X_l := 0.1312500000 \quad X01_E := 0.01607477644\, \sin(0.1224744872\, t)$$

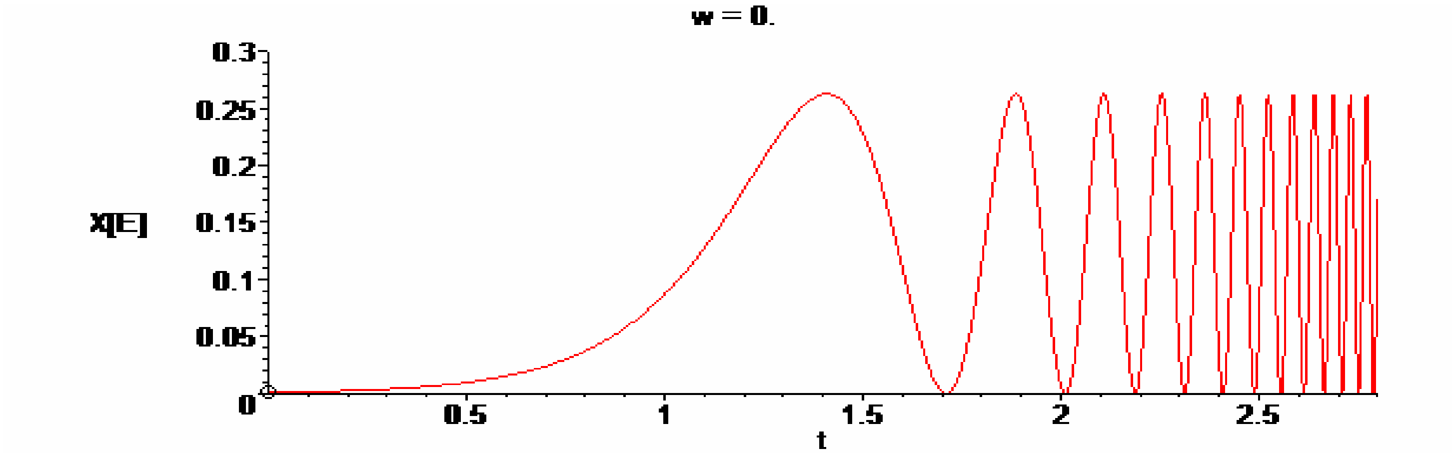
$$X1_E := 0.01607477644\, \sin(0.1224744872\, 10^w) \qquad wo := 2.65$$

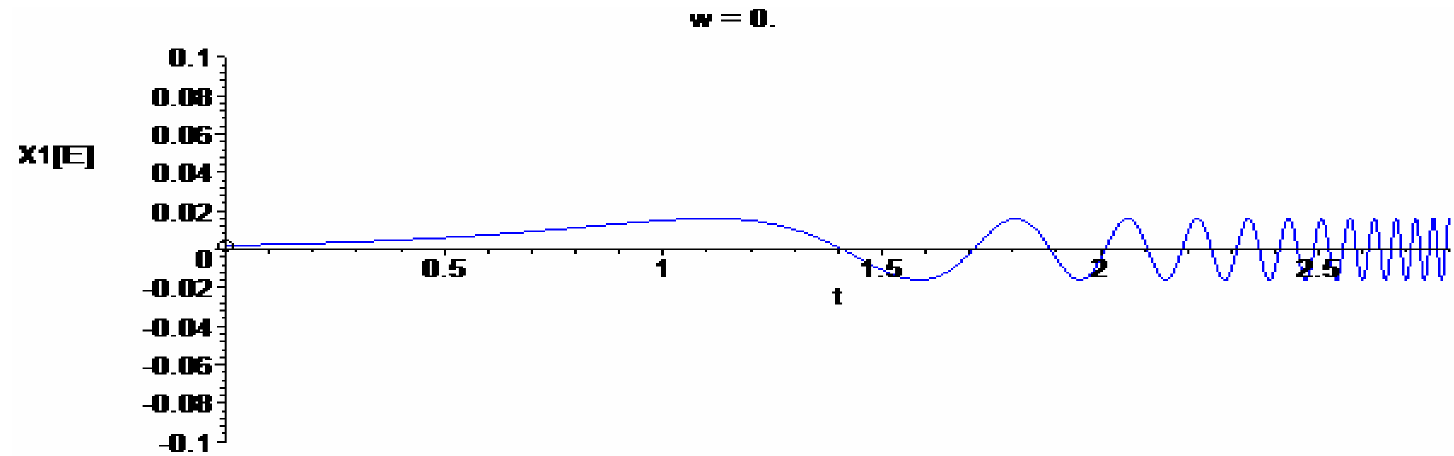


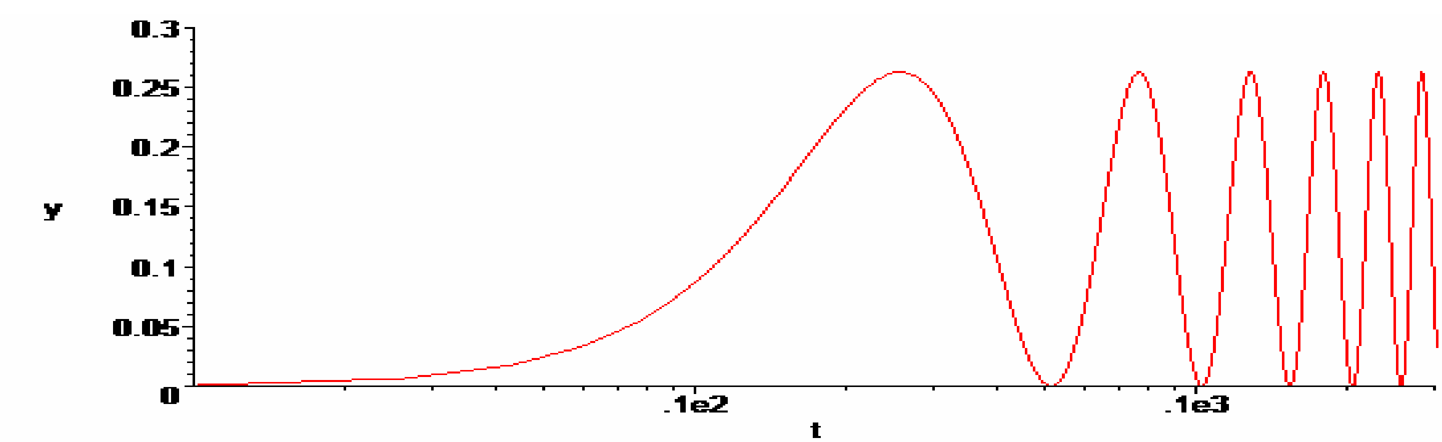



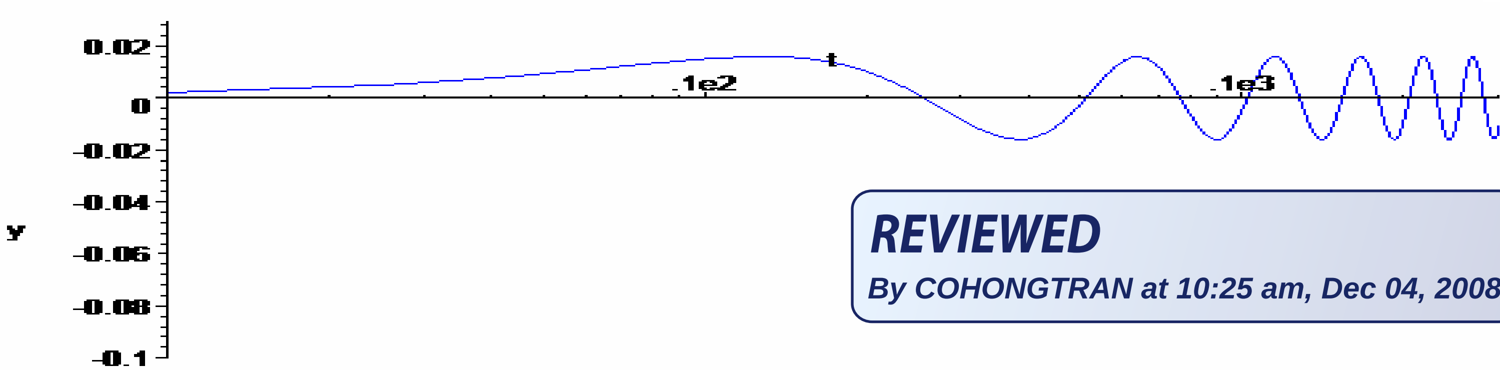




The animate graphic of X and X1 :






$$y10 := t \rightarrow -0.1312500000\ \cos(0.1224744872\ t) + 0.1312500000$$

$$y1 := 50\ y10$$

$$y10 := t \to 0.1312500000 - 0.1904751818\ 10^{-6}\ \mathrm{e}^{(-0.09999985488\ t)} \cos(101.6658374\ t) - 0.5620631121\ 10^{-9}\ \mathrm{e}^{(-0.09999985488\ t)} \sin(101.6658374\ t) - 0.5571722761\ 10^{-20}\ (0)\ (0.50438898\ 10^{11}\ \mathrm{e}^{(-0.09999985488\ t)} \cos(101.6658374\ t) - 0.17093024\ 10^{14}\ \mathrm{e}^{(-0.09999985488\ t)} \sin(101.6658374\ t))\ I - 0.5571722761\ 10^{-20}\ (0)\ (-0.50438898\ 10^{11}\ \mathrm{e}^{(-0.09999985488\ t)} \cos(101.6658374\ t) + 0.17093024\ 10^{14}\ \mathrm{e}^{(-0.09999985488\ t)} \sin(101.6658374\ t))\ I - 0.1312498095\ \mathrm{e}^{(-0.2902490119\ 10^{-6}\ t)}$$

$$y1 := 500\ y10$$

```
> mohinh:=proc(M)
> mohinh(2);
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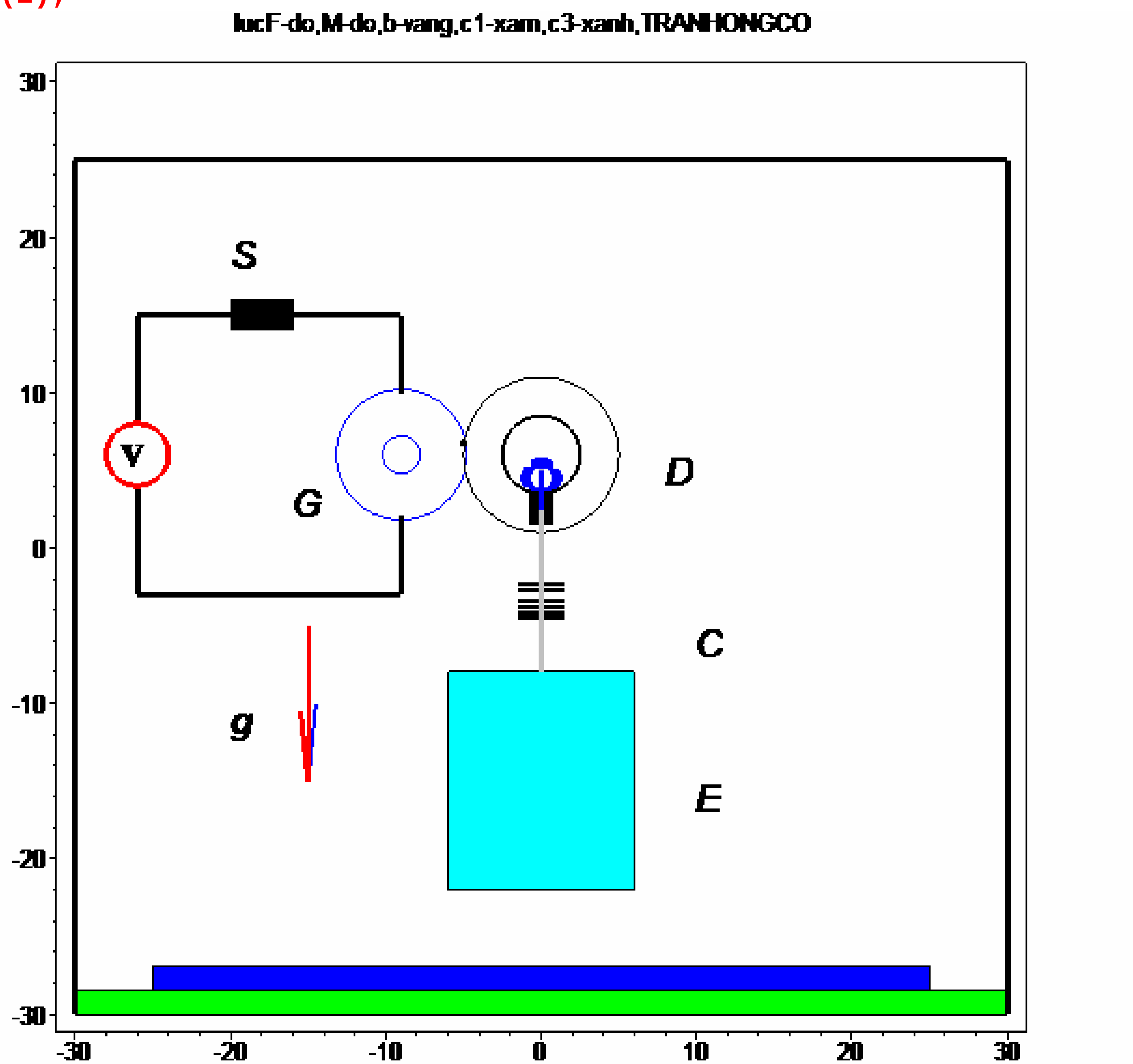


$$x_E := \frac{e_s\, r_D\, n_G\, k_C}{s\, K_M\, m_E \left( R\, C\, s^3 + s^2 + \frac{R\, r_D^{\,2}\, n_G^{\,2}\, k_C\, s}{K_M^{\,2}} + \frac{R\, C\, k_C\, s}{m_E} + \frac{k_C}{m_E} \right)}$$

$e_M := 0.05 \quad k_C := 1.5 \quad K_M := 3.2 \quad m_E := 100 \quad r_D := 2.1 \quad n_G := 4 \quad e_s := 0.05\,R\,C\,s + 0.05$

$$x_E := \frac{0.03937500000\,(0.05\,R\,C\,s + 0.05)}{s\,(R\,C\,s^3 + s^2 + 10.33593750\,R\,s + 0.01500000000\,R\,C\,s + 0.01500000000)}$$

$$X0_E := 0.1312500000 - 3.281250000\left(\sum_{\_\alpha = \mathrm{RootOf}(48 + 3200\,R\,C\,\_Z^3 + 3200\,\_Z^2 + (33075\,R + 48\,R\,C)\,\_Z)} \frac{e^{(\_\alpha\,t)}\,(128\,\_\alpha + R\,(1323 + 128\,\_\alpha^2\,C))}{9600\,R\,C\,\_\alpha^2 + 6400\,\_\alpha + 33075\,R + 48\,R\,C}\right)$$

$$R := 5000$$

$$C := \frac{1}{1000}$$

$$wo := 2.5$$

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Warning, the name changecoords has been redefined
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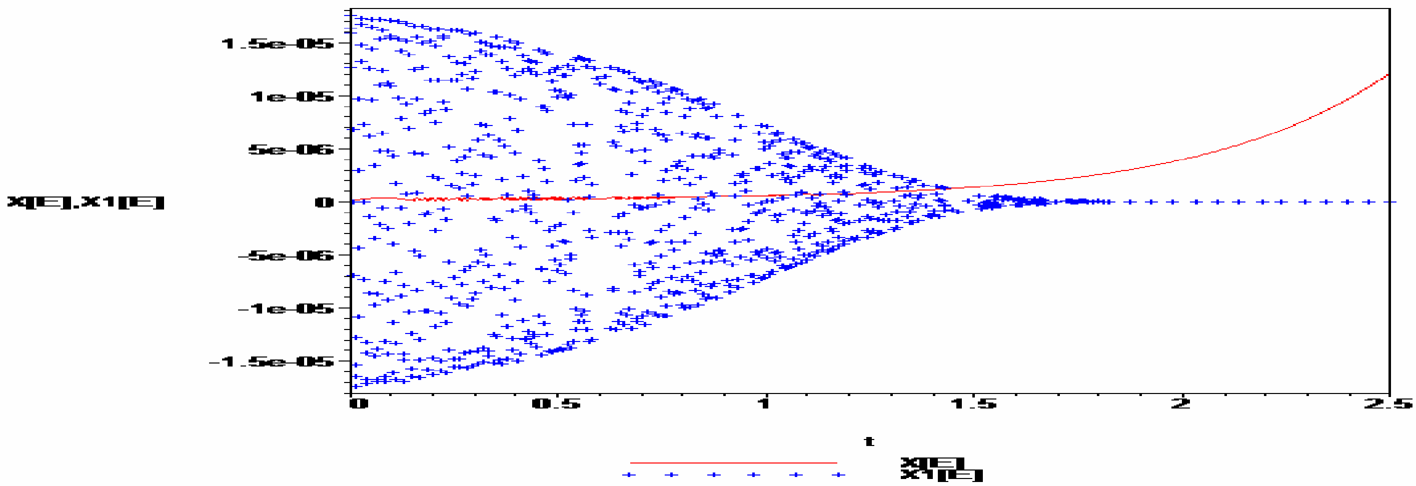


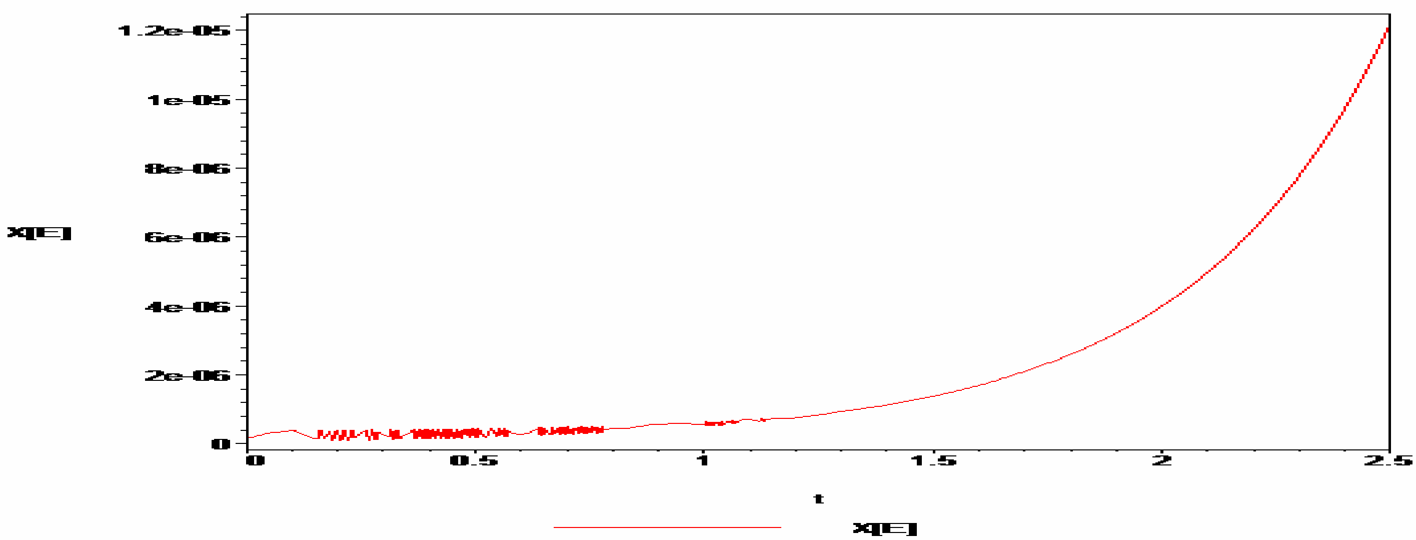

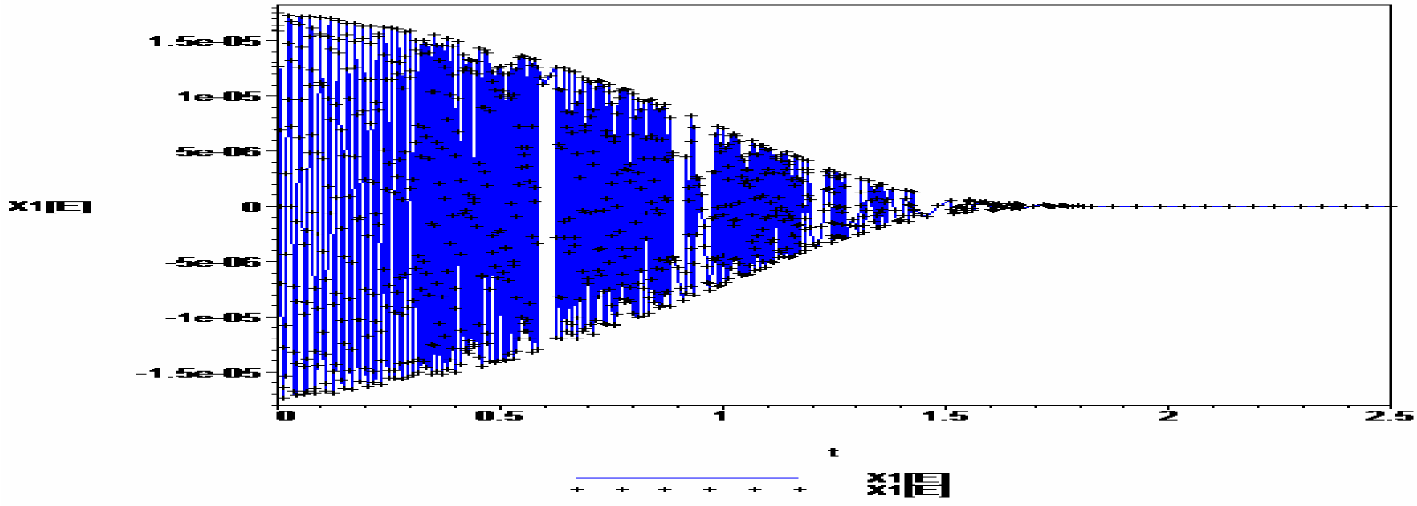


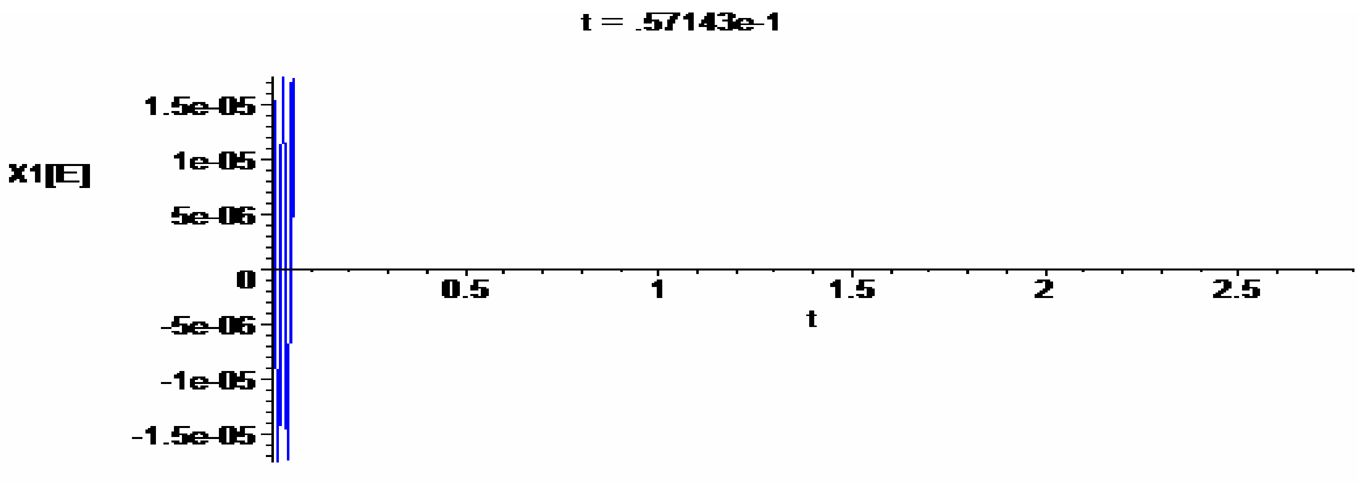


***Disclaimer:*** While every effort has been made to validate the solutions in this worksheet, the author is not responsible for any errors contained and are not liable for any damages resulting from the use of this material.



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CO.HONG.TRAN

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