The Diving Board: What Happens As I’m Falling?

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Abstract

A look at the end motion of a diving-board as a result of a load (person) jumping off of it. This project explores separation of variables to solve partial ordinary differential equations; the method used in this paper will contain a steady state and transient problem.
1 Preliminary Knowledge

In this project simplifying assumptions were made. One of these assumptions was that the diving board could be thought of as a long cantilever beam with one end supported while the other was free to rotate and bend (see Figure 1). While this isn’t necessarily true, most diving boards have a support at the end and a support about 1 foot from the supported end (see Figure 2), it proves sufficient enough to be able to model a diving board fairly closely. Another assumption was that the beam was homogeneous with uniform cross section and weight density. Therefore, the weight can be thought of as a load per unit length. The final assumption was that the only forces acting on the beam were the shear force, the weight of the beam, and damping from the air. It’s important to understand that other assumptions will be made throughout the paper that will be explained and noted at that point. Also, this project is not original work. It has been done before [2], but I am just going to go through it step by step explaining along the way just how this method works. I will also be adding the use of MATLAB, which was not covered in the original work.

![Figure 1: Simple Cantilever Beam](image1)

![Figure 2: Actual Diving Board](image2)

1.1 A Look at Symbols and Sign Conventions

Below are the symbols that are used in this project and their meanings.

- $w =$ Weight per unit Length of Beam
- $g =$ Gravitational Acceleration
- $V =$ Shear Force
- $M =$ Bending Moment

1


- $y$ = Displacement of Board
- $E$ = Modulus of Elasticity (Young’s Modulus)
- $I$ = Second Moment of Area (Area Moment of Inertia)

The following images show the sign convention used during the paper.

![Figure 3: Sign Convention for Shear and Bending](image)

2 A Quick Look at a Board Under Stress

Since this project is tied very closely with mechanics of materials, it’s important to understand how a beam acts under load. In the case of a cantilever beam with one end clamped, there are certain reactionary forces that are present, and there are certain relationships between these reactionary forces. Let’s take a look at these relationships before proceeding with the main project.

The load that is going to be of concern to this project is that of a weight per unit length acting on the beam, shear force, and a bending moment acting on the beam (see Figure 4). In order to see the relationships between these forces such as bending moment and shear, let’s take a look at an infinitesimally small piece of the beam.

![Figure 4: Infinitesimal Piece of Diving Board with Length $dx$](image)

It’s observed that the forces which I described earlier are acting on the beam as shown, and through simple equilibrium equations key concepts can start to emerge. Let’s begin by summing the moments that are acting on the beam and setting them equal to zero for equilibrium (CCW is the positive direction of moment). If this step is performed, you obtain the equation:
\[
\frac{\partial M(x, t)}{\partial x} = V(x, t)
\]  

(1)

This conclusion is a very important one. First, it can be used on any material because no assumptions were made about the material. Secondly, it provides us with a key relationship between shear force and bending moment.

Now let’s take a look at a cantilever beam that’s been bent due to pure bending (no shear forces). Let’s take another infinitesimal piece of this board for analysis, Figure 5 [1].

Figure 5: Infinitesimal Piece of Diving Board in Pure Bending

It can be observed that, relative to the beginning lengths, the top of the board was shrunk, and the bottom of the board was stretched [1]. It makes sense then, to say that at some point the length of the board is unchanged. We’ll call this point the neutral axis, meaning that the axis doesn’t change length. We can find the strain due to the bending moment by the equation

\[\epsilon = \delta / L\]

where \(\delta\) is the elongation of the board. So now we just need to find the elongation of the top of the board and divide it by the length of the neutral axis.

Figure 6: Deformation of Diving Board due to Pure Bending
The length of the neutral axis \((dx)\) can be found by using the arc length formula \(L = \rho d\theta\) where \(\rho\) is the radius of curvature of the section of board (see Figure 6) [1]. Now, if we call the distance from the neutral axis to the top of the board \(y\) (see Figure 6), then we can say \((\rho - y)d\theta\) is the length of the top of the board. Therefore, the elongation, \(\delta\), of the top of the board is the length of the top of the board minus the length of the neutral axis. When you do this, you get \(\delta = -yd\theta\). The negative sign is a good indication that things are going well because, as was said earlier, the top of the board decreased in length which is a negative elongation. Now, to find the strain, divide the \(\delta\) by the length of the neutral axis. After this is done, the formula for the strain becomes:

\[
\epsilon = -\frac{y}{\rho}
\]

Let’s assume that this board is linearly elastic (which is well justified for a diving board). After this assumption, the formula relating stress to strain can be applied to give the resulting stress that’s acting on the board. The equation is:

\[
\sigma = E\epsilon
\]

Knowing this, the equation for stress becomes:

\[
\sigma = -\frac{Ey}{\rho}
\]  

(2)

Stress is the force per unit area of the cross section, so by taking \(\sigma dA\) we can get the force acting on an infinitesimal piece of the board. It’s also known that force multiplied by distance gives you a moment. So, if we take \(\sigma ydA\) and integrate over the entire cross-sectional area of the board, we’ll get a moment that’s equal to the moment acting on the board. But, from equilibrium, we know that this moment must be opposite to the moment acting on the board [1], so the equation becomes

\[
M = -\int \sigma ydA
\]  

(3)

Now, if (2) is plugged into (3), then integration is performed, the following equation pops out:

\[
M = \frac{E}{\rho} \int y^2dA
\]  

(4)

The piece \(\int y^2dA\) is known as the area moment of inertia, \(I\). Thus, the equation boils down to:

\[
M = \frac{EI}{\rho}
\]  

(5)

It’s important to note that \(I\) is the moment of inertia of the entire cross sectional area of the board. Thus concludes our basic look at beams under load, and now we’ll be able to use these equations in the math that follows.
3 The Partial O.D.E.

Now it’s time to set up the partial differential equation that we’re going to solve. In order to do this, we have to look at yet another infinitesimal section of the beam. From Newton’s second law we know that the net force acting on the beam will be equal to the mass of the board multiplied by it’s acceleration. The total force acting on the board is given by:

\[ \text{TotalForce} = \text{NetShearForce} + \text{DragForce} + \text{Weight} \]

Or, in mathematical terms:

\[ \frac{w}{g} \Delta x \frac{\partial^2 y}{\partial t^2} = V(x, t) - V(x + \Delta x, t) - R \Delta x \frac{\partial y}{\partial t} - \frac{w}{g} \Delta x g \] (6)

Notice that we assumed that the drag force was equal to some constant multiplied by the velocity of the board and it’s length [2]. After performing some algebra to isolate the left hand partial, the following equation pops out.

\[ \frac{\partial^2 y}{\partial t^2} = -\frac{g}{w} \frac{V(x, t)}{\Delta x} - \frac{g}{w} \frac{R \Delta x \partial y}{\partial t} - \frac{g}{w} \frac{w \Delta x g}{\Delta x} \]

Now, if we let \( \Delta x \to 0 \) and simplify the remaining terms we obtain:

\[ \frac{\partial^2 y}{\partial t^2} = -\frac{1}{m} \frac{\partial V}{\partial x} - \frac{R}{m} \frac{\partial y}{\partial t} - g \] (7)

Notice that we replaced \( \frac{w}{g} \) by \( m \) which is now called the mass per unit length. But we’re not done here; take note of the \( V(x, t) \) term in the beginning of the equation. We’d like to have an equation that only depends on \( y(x, t) \) [2], so now we get to use the equations that we derived in the beginning section! Remember way back in the beginning when we a key relationship was established between \( M \) and \( V \)? Well, now we get to use it. If (1) is differentiated with respect to \( x \) one more time and plugged into (9), then the following equation is established:

\[ \frac{\partial^2 y}{\partial t^2} = -\frac{1}{m} \frac{\partial^2 M}{\partial x^2} - \frac{R}{m} \frac{\partial y}{\partial t} - g \] (8)

But we still have a problem with \( M \) being in the equation, so if we turn to (5) and differentiate it with respect to \( x \) two times and plug it into (8), then we’ll be ready to go. The important thing to remember is that \( \rho \) is the radius of curvature which is defined to be:

\[ \rho = \left[ 1 + \left( \frac{\partial y}{\partial x} \right)^2 \right]^{\frac{1}{2}} \]

If \( \partial y/\partial x \) is very tiny, that is if the beam only bends very slightly, then the preceding equation becomes:

\[ \rho = \frac{1}{\partial^2 y/\partial x^2} \]
After plugging this into (5), differentiating twice, and then plugging that into (8), the following equation pops out:

\[
\frac{\partial^2 y}{\partial t^2} = -\frac{EI}{m} \frac{\partial^4 y}{\partial x^4} - \frac{R}{m} \frac{\partial y}{\partial t} - g
\]  

Now we’re FINALLY ready to solve for the displacement \(y(x,t)\), but first we have to apply boundary conditions on the board, and, for simplicity, represent products of constants as a single constant. Upon performing these things, the equation and boundary conditions are as follows [2]:

\[
\frac{\partial^2 y}{\partial t^2} = -c^2 \frac{\partial^4 y}{\partial x^4} - k \frac{\partial y}{\partial t} - g
\]

\[
y(0,t) = 0, \quad t > 0
\]

\[
\frac{\partial y}{\partial x}(0,t) = 0, \quad t > 0
\]

\[
\frac{\partial^2 y}{\partial x^2}(L,t) = 0, \quad t > 0
\]

\[
\frac{\partial^3 y}{\partial x^3}(L,t) = 0, \quad t > 0
\]

\[
y(x,0) = f(x), \quad 0 < x < L
\]

\[
\frac{\partial y}{\partial t}(x,0) = g(x), \quad 0 < x < L
\]

Notice that the symbol \(c^2\) has taken place of \(EI/m\) and \(k\) has taken place of \(R/m\). This equation still looks pretty intimidating in all of it’s boundary value glory, but it’s actually not that hard to understand once you start taking a look at it. The main confusing thing is the boundary value notation. Let’s go through and figure out what each piece means.

The first boundary value is stating that the displacement at the clamped end of the beam \((x = 0)\) is 0 at all times [1]. The second boundary value simply states that the slope at the clamped end of the beam is zero as well for all time, which means that the clamped end is always horizontal. The third boundary value problem is stating that the bending moment is zero at the far end of the beam where it’s allowed to swing freely. This one is a little harder to see just where they came up with that notation. It comes from (5), which basically states that the bending moment of a beam is inversely proportional to the radius of curvature \((E\) and \(I\) are just constants); we also noticed a few equations ago that the radius of curvature is pretty darn close to \(\partial^2 x/\partial y^2\). If the bending moment of a beam is inversely proportional to the following equation, then we know that it’s directly proportional to \(\partial^2 y/\partial x^2\). The fourth boundary value problem comes from the consequence of (1) and states that the shear force at the end of the board where it’s free to swing is zero. The last two equations are just stating that the displacement graph is smooth and continuous. Now that the somewhat lengthy base has been set into place, it’s time to solve the partial differential equation.
4 Solving the P.D.E.

4.1 The Steady State Problem

The standard way to solve partial differential equations is to try and obtain ordinary differential equations that represent the same thing[3], but now the question becomes: How do I do that? Let’s take a look at our problem. After a very long time has passed we would expect the position of the board to be independent of time. Let’s represent this by \( v(x) \). After plugging \( v(x) \) in place of \( y(x,t) \) into (10), an ordinary differential equation emerges. We’ll call this equation the steady state problem, and it looks something like this:

\[
0 = -c^2 \frac{d^4 v}{dx^4} - g
\]  

(11)

We can’t forget to incorporate our boundary values though. The boundary values for this function are as follows:

\[
v(0) = 0
\]

\[
\frac{dv}{dx}(0) = 0
\]

\[
\frac{d^2 v}{dx^2}(L) = 0
\]

\[
\frac{d^3 v}{dx^3}(L) = 0
\]

These boundary values are a direct consequence of the boundary values that we set up earlier for the displacement. It’s pretty obvious to see that this equation is readily solvable by separation of variables[1]; the only catch is that you have to perform separation of variables about 4 times, using your boundary conditions to obtain the constants. Let’s solve this really quick. The first separation of variables results in the following equation:

\[
\frac{d^3 v}{dx^3} = -\frac{g}{c^2} x + C_1
\]  

(12)

It’s easy to see that \( C_1 = gL/c^2 \) by using our boundary condition \( v''(L) = 0 \). Separating again, we obtain this equation:

\[
\frac{d^2 v}{dx^2} = -\frac{g}{2c^2} x^2 + \frac{gL}{c^2} x + C_2
\]  

(13)

Once again, by using the boundary condition \( v''(L) = 0 \), we are able to obtain \( C_2 = -gL^2/2c^2 \). Once again, using separation on this equation, we get the following equation:

\[
\frac{dv}{dx} = -\frac{g}{6c^2} x^3 + \frac{gL}{2c^2} x^2 - \frac{gL^2}{2c^2} x + C_3
\]  

(14)
Where \( C_3 = 0 \) by the boundary condition \( v'(0) = 0 \). We only have one more separation of variables to perform. It gives us the following result:

\[
v = -\frac{g}{24c^2}x^4 + \frac{gL}{6c^2}x^3 - \frac{gL^2}{4c^2}x^2 + C_4
\]  
(15)

Where \( C_4 = 0 \) by the boundary condition \( v(0) = 0 \). So \( v(x) \) is given by the equation:

\[
v(x) = -\frac{g}{24c^2}x^4 + \frac{gL}{6c^2}x^3 - \frac{gL^2}{4c^2}x^2
\]  
(16)

It’s important to understand that \( v(x) \) is displacement of the beam, but it’s the displacement as \( t \to \infty \). So, it’s kind of like how the board is going to deform while it’s just sitting still, or before a person decides to jump off of it. Therefore, it’s this equation that tells us if the board is sagging due to it’s weight, and it will determine what each piece of the board will oscillate around. Hence, it’s a pretty important equation. It’s also important to realize that we actually did need the boundary conditions for something other than kicks and giggles. At first, you may wonder why we ever needed them, but it’s obvious that they are very important after the derivation of the steady state equation.

### 4.2 The Transient Problem

It’s all good and well to know how the board acts as \( t \to \infty \), but what about all the other time when time isn’t insanely large? This is where the transient problem comes into play. We’ll symbolize the transient solution by \( w(x,t) \).[3] The transient solution is also the displacement of the beam, but it’s the displacement when time isn’t insanely large, so it’s this solution that should give us the equations to describe what looks like an oscillation of the beam (i.e. it will give us the dynamic motion whereas \( v(x) \) only gives us the static displacement).

But, the question about how to get the transient problem, let alone the solution, still remains unsolved. In order to obtain the problem, we have to realize that if we want displacement at all other time except for insanely large quantities, we must take the displacement function that describes all time whether large or small and subtract the displacement function that describes only large amounts of time. This should give us the displacement at the small and intermediate times.

In this case, the displacement function that describes all time is \( y(x,t) \). Remember, \( v(x) \) was obtained by observing that at very large quantities of time \( y(x,t) \to v(x) \). So, in order to get the displacement at the small and intermediate times, we must take \( y(x,t) - v(x) \). This is where we get the transient problem, and it’s purpose is to tell us how the board acts at times that aren’t insanely large. The transient problem is given by \( w(x,t) = y(x,t) - v(x) \).[3] Notice that the transient problem can also be written as \( y(x,t) = w(x,t) + v(x) \), this equation makes sense because as stated before \( w(x,t) \) describes what’s happening at small and intermediate time lengths and \( v(x) \) describes what’s happening
at very large time lengths. Hence, if you add the two, you’ll get the motion of the board at all time lengths, which is exactly what we want!

We already have a solution for $v(x)$, so now we just have to find a solution for $w(x,t)$. If $w(x,t)$ is substituted in (10), the following equation emerges[3]:

$$\frac{\partial^2 w}{\partial t^2} = -c^2 \frac{\partial^4 w}{\partial x^4} - k \frac{\partial w}{\partial t}$$

(17)

$$w(0, t) = 0, \ t > 0$$

$$\frac{\partial w}{\partial x}(0, t) = 0, \ t > 0$$

$$\frac{\partial^2 w}{\partial x^2}(L, t) = 0, \ t > 0$$

$$\frac{\partial^3 w}{\partial x^3}(L, t) = 0, \ t > 0$$

$$w(x, 0) = f(x) - v(x), \ 0 < x < L$$

$$\frac{\partial w}{\partial t}(x, 0) = g(x), \ 0 < x < L$$

Notice that the following equation still has partial derivatives in it. Weren’t we trying to get rid of the partial’s? Yes, that’s the main goal, but $w(x,t)$ is still a function of time and position. We did get rid of that pesky little $g$ that was tagging along behind, so that’s one step forward. The main significance behind getting it into this form is that we can now use separation of variables. The method of separation of variables involves guessing that the solutions looks like a product of a function of $x$ and a function of $t$. So, in other words, we are assuming the solution looks something like this: $w(x,t) = L(x)Z(t)[5]$. If we assume that the solution looks like this and plug it into (17), we get the following equation[3]:

$$Z''(t)P(x) = -c^2 Z(t)P'''(x) - kP(x)Z'(t); \ 0 < x < L, \ t > 0$$

(18)

$$P(0)Z(t) = 0, \ t > 0$$

$$P'(0)Z(t) = 0, \ t > 0$$

$$P''(L)Z(t) = 0, \ t > 0$$

$$P'''(L)Z(t) = 0, \ t > 0$$

Notice that for the initial conditions to hold true, either $Z(t) = 0, \ t > 0$ is true, which would lead to an insanely trivial answer, or $P(0) = P'(0) = P''(L) = P'''(L) = 0, \ t > 0$ is true. In order to avoid the mind numbingly boring answer that the first choice gives, we’ll say that the second one is the case that we’re interested in[3].

9
4.3 Guessing In Differential Equations

You may be asking yourself if guessing a solution is really a valid thing to do. Can we really just guess a solution? In differential equations, a lot of solutions are results of educated guesses. For example, when you’re dealing with a first order differential equation \( y' = ay \), we can solve this problem and obtain \( y = Ce^{at} \) where \( C \) is found through initial conditions and \( a \) is just a coefficient. Now, when we looked at second order differential equations such as \( y'' + py' + qy = 0 \), we were motivated by the first order solution and guessed the solution to this problem looks like \( y = e^{\lambda t} \). This lead us to developing the characteristic equation, polynomial, and roots. We were basically finding the values of \( \lambda \) that would make the solution work. It’s kind of analogous in this case; we are making a logical guess and making it work by forcing it through the use of boundary conditions. Now, back to our problem.

The main purpose in calling the procedure separation of variables is because we actually have to separate the variables, with everything that depends on \( x \) to the left and everything that depends on \( t \) to the right, by using simple algebra.

\[
\frac{Z''(t) + kZ'(t)}{-c^2 Z(t)} = \frac{P''''(x)}{P(x)} = \lambda; \quad 0 < x < L, \quad t > 0
\]  

(19)

This equation is stating that two functions, that depend on two totally different variables, must equal each other. When you have two functions that depend on different variables, the only way that they can be equal to each other at all times is if they’re both equal to a constant\[5][3]. This constant is denoted by the term \( \lambda \), and you can kind of think of it in this context as a proportionality constant.

Once again, if we perform some simple algebraic moves, we can come up with two ordinary differential equations.

\[
P''''(x) - \lambda P(x) = 0; \quad 0 < x < L
\]  

(20)

\[
Z''(t) + kZ'(t) + \lambda c^2 Z(t) = 0; \quad t > 0
\]  

(21)

Yes! We finally have our ordinary differential equations! Now we can solve \( L(x) \) and \( Z(t) \) and multiply them together to obtain \( w(x, t) \). But, keep in mind that \( \lambda \) is still unknown. So, not only do we have to solve these problems, but we have to find out what the value of \( \lambda \) is. It’s right about here that I’m going to abandon the mathematics of this project. After this point, the problem becomes too complicated for the material that we have covered in this course. I can tell you however, that to start to solve this problem you must create a two point boundary value problem with (20) using your boundary conditions to help you. After that, the mathematics gets into many things beyond the scope of this class. I’ll give you the final equation just so that you can see what I’m talking about.
4.4 The Final Equation

\[ y(x, t) = v(x) + \sum_{n=1}^{\infty} X_n T_n \]

\[ v(x) = -\frac{gL^2 x^2}{4c^2} + \frac{gLx^3}{6c^2} - \frac{gx^4}{24c^2} \]

\[ P_n = \cos(\alpha_n x) - \cosh(\alpha_n x) - \frac{\cosh(\alpha_n L)}{\sinh(\alpha_n L)} \frac{\cos(\alpha_n L)}{\sin(\alpha_n L)} e^{-\frac{1}{2}kt} \]

\[ Z_n = [A_n \cos(\mu_n t) + B_n \sin(\mu_n t)] \]

\[ \mu_n = \frac{1}{2} \sqrt{4\alpha_n^2 c^2 - k^2} \]

I should let you know that a certain substitution was made, that is \( \lambda = \alpha^4 \). I should also let you know that,

\[ \alpha_n = \frac{(2n + 1)\pi}{2L} \]

Where \( n \) is any integer. And you should also know that \( A_n \) and \( B_n \) are arbitrary constants, provided that \( 0 \leq k < 2c \alpha_n^2 \).

5 What Just Happened?

To be perfectly honest, most all of the math that’s involved in finding the solutions to (20) and (21) utilizes a lot of techniques and mathematics that are beyond the scope of the class. But, in order to avoid all of the confusing math that we haven’t learned, we can utilize technology. The beautiful thing about MATLAB is that I can punch in equations and get pictures of their solutions without having to go through a lot of the confusing stuff, so that’s exactly what I did. I just want to see a solution, and from their I can tell if my model is correct, or if my model just plain stinks.

Figure 7 shows the displacement of the board as a function of time at various points along the board, and Figure 8 is just a close up of the same picture. Notice that in the first graph the displacement representing the end of the board is oscillating around -.15 meters, or -15 centimeters. This is a very important finding; this tells us that the board is sagging due to its weight, which is to be expected. I chose a 3 meter long board to run through MATLAB, which is equivalent to about 9 feet. That’s a huge board! No wonder it’s sagging because it has no fulcrum to support it, so this shows us that our equations model the board very well.

Also notice that the closer we get to the clamped end of the board, the smaller the displacement gets. This is also a crucial finding because it agrees
Figure 7: Displacement of the Board Far View

Figure 8: Displacement of the Board Close View
with observation. Overall, the graph just looks like the motion of a diving board. You may be wondering how I found all of my constants; for my constants I looked up the material properties of diving board material and chose a length of board. I chose an arbitrary damping constant and value of $\lambda$, and for my initial conditions on (20) and (21) I used the properties of the diving board plus other techniques that are found in the book *Mechanics of Materials* [1], but for (21) I chose fictional initial conditions. While this may not be the most accurate method I was forced to do so because I simply didn’t have enough information.

6 Improving the Model

While our model works, it could also be improved. As stated before, most diving boards have a fulcrum that acts part way down the board. If this fulcrum was added, initial conditions would change as well as boundary conditions [4]. Another thing that could be added is a taper to the board. This would change the weight distribution along the board, and it would also throw out the assumption that the board had a uniform cross section. Thus, our $J$ would actually be a function of $x$ and things would get extremely complicated.

7 Conclusion

Other than these improvements, the model works fairly well. Some might be wondering why this problem is significant, and the answer is fairly simple. At some point in a diver’s life, they’re going to want to know how to obtain the greatest height out of their jump; this exercise lays the foundation for such a question. From this project you could jump into maximization and things of that nature that I decided to not delve into. Also, companies that build diving boards want to know how to build the best diving board; once again, this project lays the foundation. So, it can be seen that this experiment is important to some people.

Hopefully, if I do another project again later in life, I can take these results and delve into maximization. The bad thing about the project was that it deals with some math that’s way over my head, but I believe in a couple years I’ll be able to tackle these problems. Overall, the project turned out to be successful and I enjoyed the challenge of learning.
8 Appendix

%steady state

function vprime=steadystate(x,v)
global g c

vprime=zeros(4,1);

vprime(1)=v(2);
vprime(2)=v(3);
vprime(3)=v(4);
vprime(4)=-g/(c^2);

%graph of steady state

global g c
g=9.81;
c=10;

[x,v]=rk4(@steadystate,[0,3],[0;-.009;.100;-.050],.01);
plot(x,v(:,1))

%Function that relies on x

function Xprime=EX(x,X)
global lambda

Xprime=zeros(4,1);

Xprime(1)=X(2);
Xprime(2)=X(3);
Xprime(3)=X(4);
Xprime(4)=lambda*X(1);

%graph of function that depends on x

global lambda
lambda=3*pi/2;
[x,X]=rk4(@EX,[0,3],[0;.1463;.193;0],.01);
plot(x,X(:,1))

%Function that relies on time

function Tprime=Tee(t,T)
global k lambda c

Tprime=zeros(4,1);
Tprime(1)=T(2);
Tprime(2)=-k*T(2)-lambda*c^2*T(1);

% graph of function that depends on time

global lambda c k
k=.45044;
c=10;
lambda=3*pi/2;

[t,T]=rk4(@Tee,[0,10],[-.08;.08;0;0],.01);
plot(t,T(:,1))

% Combination of the three mfiles or the Final Equation

y_1=X(3,1).*T(:,1)+v(3,1);
plot(t,y_3,'b')
hold on

y_2=X(30,1).*T(:,1)+v(30,1);
plot(t,y_5,'k')
hold on

y_3=X(300,1).*T(:,1)+v(300,1);
plot(t,y_6,'g')

title('Displacement Vs. Time at Various Points')
xlabel('t')
ylabel('y')
legend('.03 m from end of board','.3 m from end','end of board')
References


