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Chapter 1 : Differential Equations - Boundary Value Problems

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Due to the nature of the mathematics on this site it is best views in landscape mode. If your device is not in landscape mode many of the equations will run off the side of your device should be able to scroll to see them and some of the menu items will be cut off due to the narrow screen width. Boundary Value Problems Before we start off this section we need to make it very clear that we are only going to scratch the surface of the topic of boundary value problems. There is enough material in the topic of boundary value problems that we could devote a whole class to it. The intent of this section is to give a brief and we mean very brief look at the idea of boundary value problems and to give enough information to allow us to do some basic partial differential equations in the next chapter. Now, with that out of the way, the first thing that we need to do is to define just what we mean by a boundary value problem BVP for short. With initial value problems we had a differential equation and we specified the value of the solution and an appropriate number of derivatives at the same point collectively called initial conditions. For second order differential equations, which will be looking at pretty much exclusively here, any of the following can, and will, be used for boundary conditions. We will also be restricting ourselves down to linear differential equations. We will, on occasion, look at some different boundary conditions but the differential equation will always be on that can be written in this form. None of that will change. The changes and perhaps the problems arise when we move from initial conditions to boundary conditions. One of the first changes is a definition that we saw all the time in the earlier chapters. If any of these are not zero we will call the BVP nonhomogeneous. It is important to now remember that when we say homogeneous or nonhomogeneous we are saying something not only about the differential equation itself but also about the boundary conditions as well. When solving linear initial value problems a unique solution will be guaranteed under very mild conditions. In that section we saw that all we needed to guarantee a unique solution was some basic continuity conditions. With boundary value problems we will often have no solution or infinitely many solutions even for very nice differential equations that would yield a unique solution if we had initial conditions instead of boundary conditions. In fact, a large part of the solution process there will be in dealing with the solution to the BVP. Or maybe they will represent the location of ends of a vibrating string. So, the boundary conditions there will really be conditions on the boundary of some process. We know how to solve the differential equation and we know how to find the constants by applying the conditions. Example 1 Solve the following BVP. This next set of examples will also show just how small of a change to the BVP it takes to move into these other possibilities. Example 2 Solve the following BVP. Example 3 Solve the following BVP. This, however, is not possible and so in this case have no solution. So, with Examples 2 and 3 we can see that only a small change to the boundary conditions, in relation to each other and to Example 1, can completely change the nature of the solution. All three of these examples used the same differential equation and yet a different set of initial conditions yielded, no solutions, one solution, or infinitely many solutions. Note that this kind of behavior is not always unpredictable however. Also, note that with each of these we could tweak the boundary conditions a little to get any of the possible solution behaviors to show up i. Example 4 Solve the following BVP. All of the examples worked to this point have been nonhomogeneous because at least one of the boundary conditions have been non-zero. Example 6 Solve the following BVP. Example 7 Solve the following BVP. Example 8 Solve the following BVP. Because of this we usually call this solution the trivial solution. Sometimes, as in the case of the last example the trivial solution is the only solution however we generally prefer solutions to be non-trivial. This will be a major idea in the next section. Before we leave this section an important point needs to be made. So, there are probably several

natural questions that can arise at this point. The answers to these questions are fairly simple. First, this differential equation is most definitely not the only one used in boundary value problems. It does however exhibit all of the behavior that we wanted to talk about here and has the added bonus of being very easy to solve. So, by using this differential equation almost exclusively we can see and discuss the important behavior that we need to discuss and frees us up from lots of potentially messy solution details and or messy solutions. We will, on occasion, look at other differential equations in the rest of this chapter, but we will still be working almost exclusively with this one. There is another important reason for looking at this differential equation. Admittedly they will have some simplifications in them, but they do come close to realistic problem in some cases.

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