DEPARTMENT OF MATHEMATICS
MATHS 761: Ordinary Differential Equations and Dynamical Systems

Hints for Laboratory 1

This handout contains detailed hints on how to do each of the tasks listed in sections 2 and 4 of the handout 'Notes for Laboratory 1'.

2 Getting started with XPP

1. Logging in: You should check your login works **before** you come to the first laboratory. If there are any problems, see your lecturer.

2. Create a new folder:

   (i) Double-click on the 'User Home Directory' icon.

   (ii) Click on 'New Folder'.

   (iii) Change the folder name to `xpp`.

3. Create an .ode file:

   (i) You can use any text editor you like; one that is easy to use is NotePad++.

   (ii) Click on the Start Icon and select 'All Programs', 'Editors', 'Notepad++', then 'Notepad++".

   (iii) When the text editor running, type in the following:

```
# quadratic two-dimensional ODE
dx/dt=x^2-a
dy/dt=-y
par a=1
init x=0,y=1
done
```

   (iv) Select 'Save As' from the 'File' menu.

   (v) Click on 'Desktop' on the left, then 'User Home Directory', and 'xpp'.

   (vi) Type `quadratic.ode` in the 'File name' box, select 'All types (*.*)' in the 'Save as type' box, and click on Save.

   (vii) At this point you can exit from the text editor or you can leave the editor window open in case you want to edit the file quadratic.ode again before the end of the session.

4. You are strongly recommended to visit the XPP website to read about the formatting of .ode files. If you have any questions, ask your lecturer.

5. To start an X-Win32 session:

   (i) Go to the Start menu, select 'All Programs', 'Utilities', 'X-Win32 2010' and then 'X-Win32 2010'.

   (ii) You will get a window called 'Welcome - X-Win32 2010' which asks 'What would you like to do?' You should just ignore this window (but do not close it).

   (iii) You only need to start X-Win32 once.

6. To start XPP:

   (i) Go to the Start menu, select 'All Programs', then 'Math & Stats' then 'xpp'.

   (ii) If you get a window asking 'Allow the connection from 127.0.0.1', click 'Allow'.

   (iii) If everything is working correctly a small window with 'Select an ODE file' at the top will appear. If the window does not appear, try Steps 5 and 6 again. If this still fails, ask for help from your lecturer or a lab demonstrator.

7. You now need to tell XPP which equations to use:

   (i) In the XPP window that appeared in the last step, click on the line `xpp`. This opens the xpp directory you made in Step 2.

   (ii) Then click on `quadratic.ode`.

   (iii) You should now see a new window with the title 'XPP Ver 5.98 >>quadratic.ode'.

   (iv) If you can see this, you are successfully running XPP. If you cannot see this, ask for help.

4 Tasks for Laboratory 1

This section gives you some hints on how to do the tasks needed for Laboratory 1. Refer to the handout 'Notes for Laboratory 1' for more details.

1. For the system of equations above, it is helpful to look at the phase plane with $-2 < x < 2$, $-2 < y < 2$. To change from the default x-t window to an y-x window:

   (i) Select (V)iewaxes, then 2D.

   (ii) In the '2D View' window that appears, change the X-axis variable to X (from T) and change the Xmin and Xmax values to -2 and 2.

   (iii) Change the settings for the y-axis similarly.

   (iv) Press OK.

   (v) The main window should now show 'Y vs X'.

2. Next integrate the equations:

   (i) Press (I)nitialconds, and then (G)o.

   (ii) A curve will appear corresponding to the solution starting from the initial condition specified in 'quadratic.ode', i.e., from $x = 0$, $y = 1$.

   (iii) You can specify other conditions as well, without modifying 'quadratic.ode'. For instance to start the solution at $x = 0.5$, $y = 0.25$ select (I)nitialconds, and then (N)ew. Now type the new value of x in the input bar at the top of the window, and press Enter. Next type the new value of y and press enter. You will see an additional curve being drawn.

   (iv) If you want to plot solutions from initial conditions selected with the mouse, press (I)nitialconds, and then m(I)ce. Then click on the desired points in the $x - y$ window. When you have seen enough solutions, press Escape.

   (v) You can use (I)nitialconds, (R)ange to draw a range of initial conditions at once. Experiment with this if you have time.

3. Look through the options in the 'Initialconds' menu.

4. To change the value of the parameter a:

   (i) Select (P)arameters, type 'a' and Enter, change the value of a from 1 to 2, then Enter.

   (ii) Press Enter once more to exit from the parameter interface.

   (iii) Now the next time you do (I)nitialconds it will use this new parameter value.

5. To zoom in and out:

   (i) Select (W)indow/zoom, then select (Z)oom In.

   (ii) Select an area by pointing somewhere, and dragging the mouse to the other corner of the area. Now this area is shown close-up. Note that only the most recently drawn trajectory will be shown.

   (iii) Try zooming in and out. What does (F)it do?

   (iv) You can also reset the window dimensions from the (V)iewaxes menu as outlined in Step 1 above.

   (v) Before going on you may wish to clear the window by selecting (E)rase from the main menu.

6. Now set the parameter 'a' back to 1 using the method described in step 4. To find the equilibrium points:

   (i) Select (S)ing pts, then (M)ouse, click on a point somewhere in the $x - y$ window, and click 'NO' for 'Print Eigenvalues?'.

   (ii) XPP will find one of the equilibria and report its position and stability in a new window.

   (iii) If you get a question 'Draw Strong Sets?' or 'Draw Invariant Sets?' click 'NO'.

   (iv) The equilibria found will be shown by a circle or triangle on the phase portrait.

   (v) The 'Equilibria' window gives you information about the equilibria. For instance if XPP finds the equilibrium at $(-1, 0)$ it will report $r- = 2$ in the equilibria window, meaning that there are two real negative eigenvalues. (In this window c stands for complex, with positive or negative real parts and im for purely imaginary.)

   (vi) Repeat the process above to find the position and stability of the other equilibrium point.

   The 'AUT' part of XPPAUT stands for AUTO, which is software you can use to continue solutions as parameters are varied. In this case you could use 'File' and 'AUTO' to continue the equilibrium solution in a. But we will leave this for another time.

7. **Notes about plotting and printing phase portraits**:

   (i) XPP does not automatically save orbits for plotting.

   (ii) If you draw a curve that you want to include in your final phase portrait, select (G)raphic stuff from the options menu, then (F)reeze, then (F)reeze again. This will save the last curve that was drawn.

(iii) Next time you freeze a curve it will be added to the set of curves already frozen.

(iv) Selecting (O)n Freeze freezes all the curves you draw.

(v) To save a picture, send the picture to a postscript file: select (G)raphic stuff, then (P)ostscript, then OK to select the default postscript parameters (black and white or colour, landscape or portrait, etc). Type in a filename in the 'Print postscript' window that appears (for example, the default is quadratic.ode.ps), and click OK.

(vi) There should now be a new file in your xpp directory, with the filename ending with '.ps'.

(vii) Doubling clicking on this file will open 'PDFCreator 0.9.9'. Type a file name into the 'Document Title' box, for instance 'quadratic.pdf', and click 'Save'. Your .pdf file will then open in Adobe Reader.

(viii) Alternatively, you can open your file in GSView. Open GSView by going to the Start menu, 'All Programs', 'Utilities', 'Ghostgum', 'GSview 4.9'. Select 'File', 'Open' in the GSView window and select your .ps file.

8. Change the step size by selecting nUmerics, then Dt.

(i) First make the step size larger, by setting Dt=0.5. Integrate from initial condition $(x, y) = (0.8, 1.4)$. Notice how the solution curve has 'corners'. This is sometimes an indication that the step size is too large and the numerical solution might give poor results. You must always check that your solutions curves (for continuous systems) are smooth.

(ii) See how small you need to make the step size so that you have a nice smooth solution curve.

(iii) Notice that if you make the step size too small (try Dt=0.0001) the computation time is very high and XPP has data storage issues.

9. (i) To quit XPP select (F)ile, (Q)uit, and 'YES'.

(ii) To log off click on 'Start' and then select 'Log off'.