

Wave Equation Example

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Wave Equation: Computes numerical approximations of the solutions of the wave equation $u_{tt} = c^2 u_{xx}$.

```
[1]: # load needed packages
import numpy as np;
import matplotlib;
import matplotlib.pyplot as plt;

font = {'family' : 'sans-serif',
        'weight' : 'normal',
        'size'   : 10}

matplotlib.rc('font', **font)
```

```
[2]: print("setup the paramaters and initial conditions")
deltaT = 1e-1; num_pts = int(5e2) + 1; L = 1e1; c = 1e0; A = 1e0;
x = np.linspace(-L,L,num_pts); deltaX = x[1] - x[0];

num_timesteps = int(1.5e2);

run_case = 'hat1';

if run_case == 'hat1':
    L1 = 0.2*L;
    i0 = int(np.round((0 + L)/deltaX));
    i1 = int(np.round((-L1 + L)/deltaX)); i2 = int(np.round((L1 + L)/deltaX));
    A = 3.0/L1;
    phi = 0*x;
    xx = x[i1:i0+1]; phi[i1:i0+1] = A*(xx + L1);
    xx = x[i0:i2]; phi[i0:i2] = A*(L1 - xx);
    psi = 0*x + 0.0;
else:
    raise Exception('case not recognized');
```

setup the parameters and initial conditions

```
[3]: print("solve the wave equation using a numerical approximation for the_
      →integral");
      # compute the solution
      u_list = [];
      for k in range(0,num_timesteps):
          num_x = x.shape[0]; t = k*deltaT; u = 0*x;
          if k % 10 == 0: print("k = %.4d"%k)
          for j in range(0,num_x):
              x1 = x[j];
              i1 = np.max([int(np.round((x1 - c*t + L)/deltaX)),0]);
              i2 = np.min([int(np.round((x1 + c*t + L)/deltaX)),num_pts - 1]);
              int_psi = 0.5*deltaX*(psi[i1] + 2.0*np.sum(psi[i1+1:i2-1] + psi[i2]));
              u[j] = 0.5*(phi[i1] + phi[i2]) + (1.0/2.0*c)*int_psi;

      u_list.append(u);
```

solve the wave equation using a numerical approximation for the integral

```
k = 0000
k = 0010
k = 0020
k = 0030
k = 0040
k = 0050
k = 0060
k = 0070
k = 0080
k = 0090
k = 0100
k = 0110
k = 0120
k = 0130
k = 0140
```

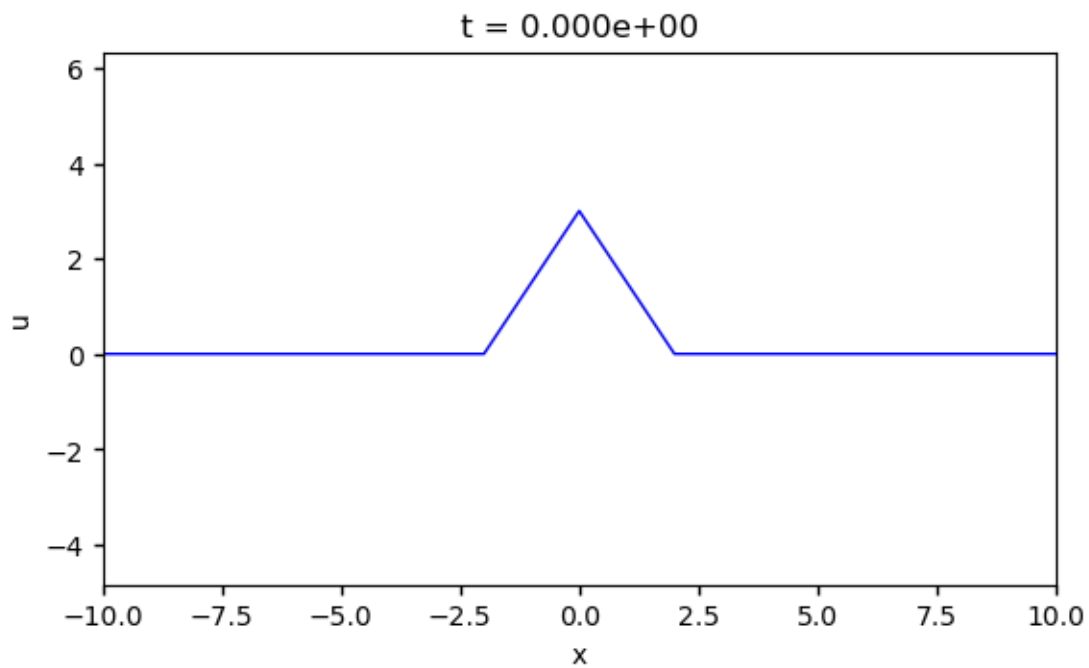
```
[4]: print("show the results");
      # Plot the results
      num_show = 15; skip = int(num_timesteps/num_show);
      for k in range(0,num_timesteps,skip):
          u = u_list[k];
          # plot the result u(x,t)
          plt.figure('wave equ t=%.3d'%k,figsize=(19.2/3.0,10.8/3.0));
          plt.clf();
          plt.title('t = %.3e'%(k*deltaT));
          plt.plot(x,u,'b-',lw=1);
          plt.xlabel('x'); plt.ylabel('u');
          plt.axis('equal');
```

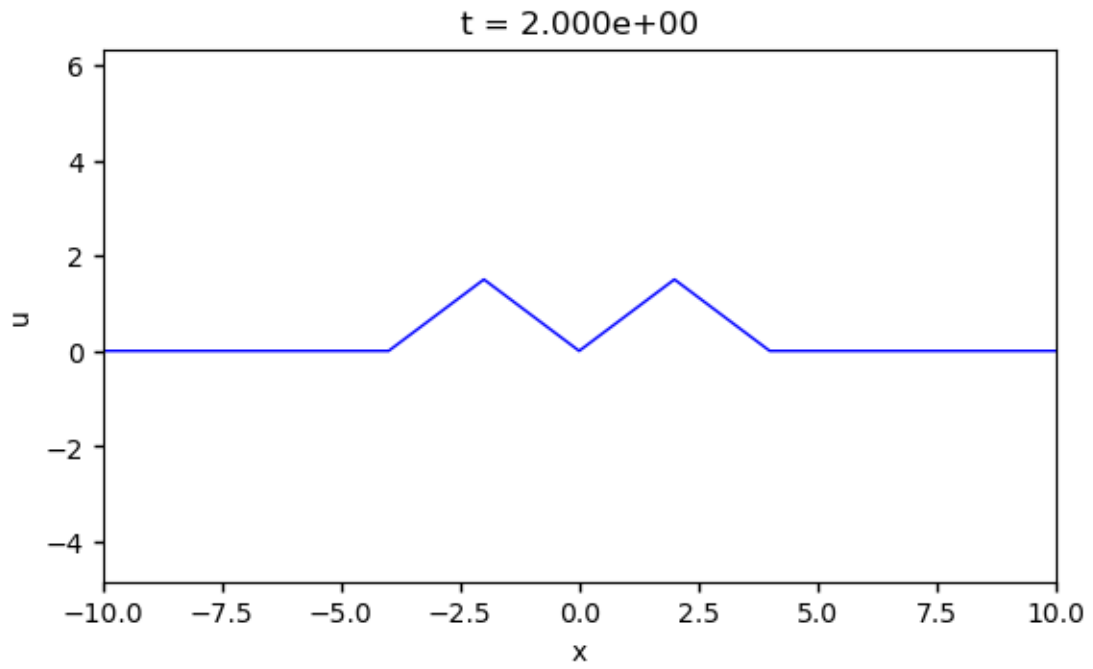
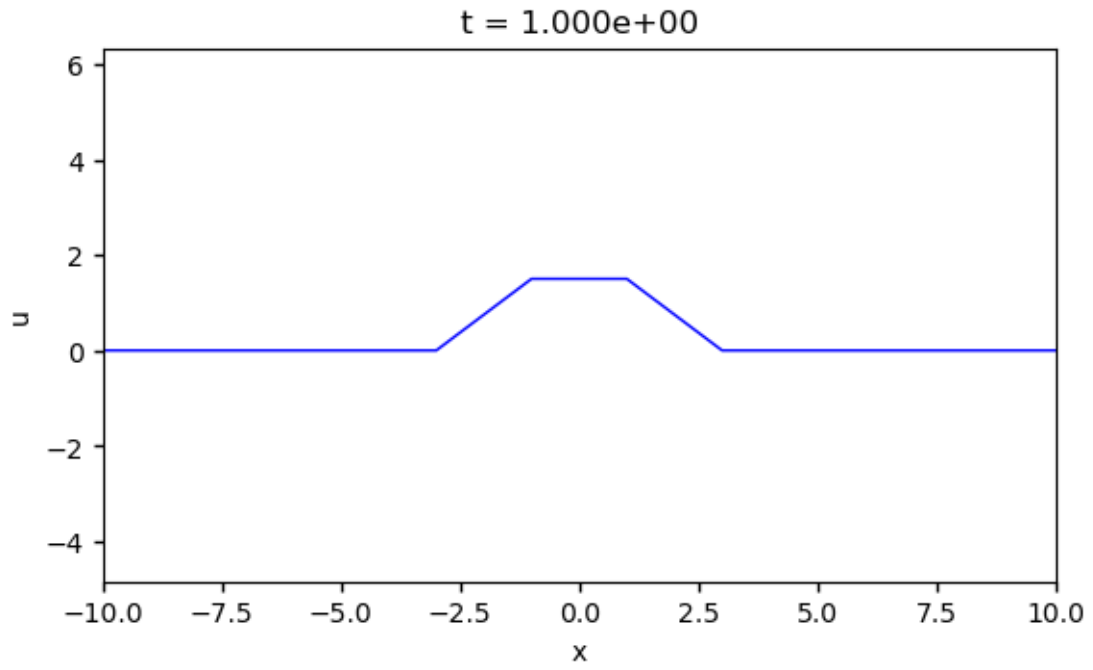
```
plt.xlim([-L,L]); plt.ylim([0,A]);
ax = plt.gca();
ax.xaxis.set_tick_params(width=1);
ax.yaxis.set_tick_params(width=1);

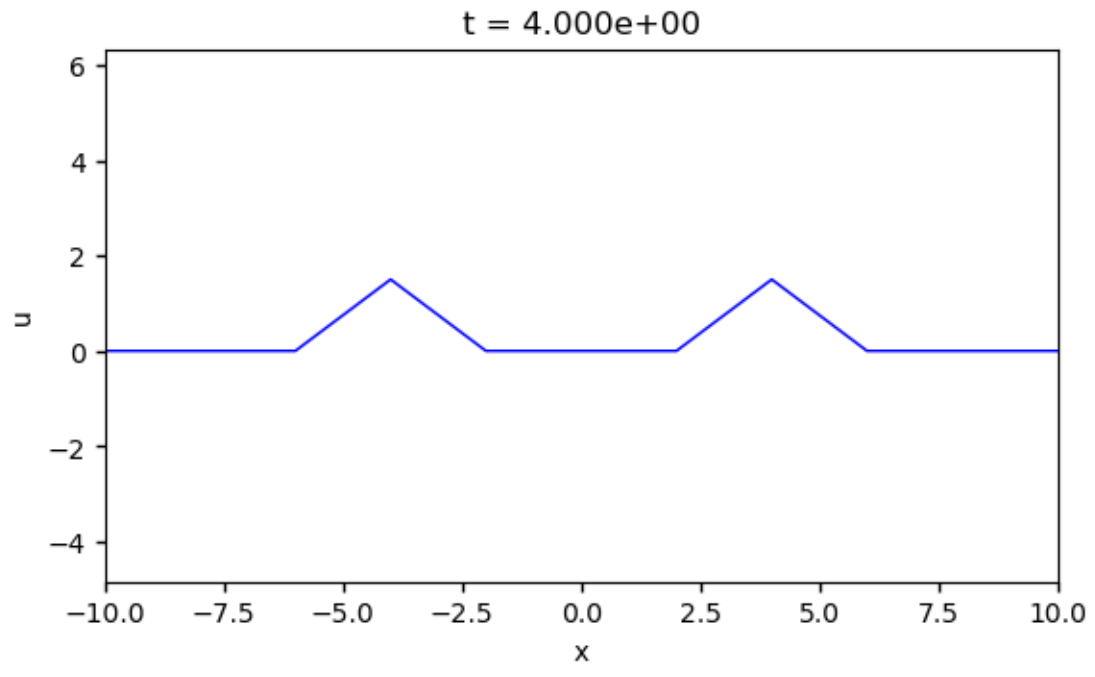
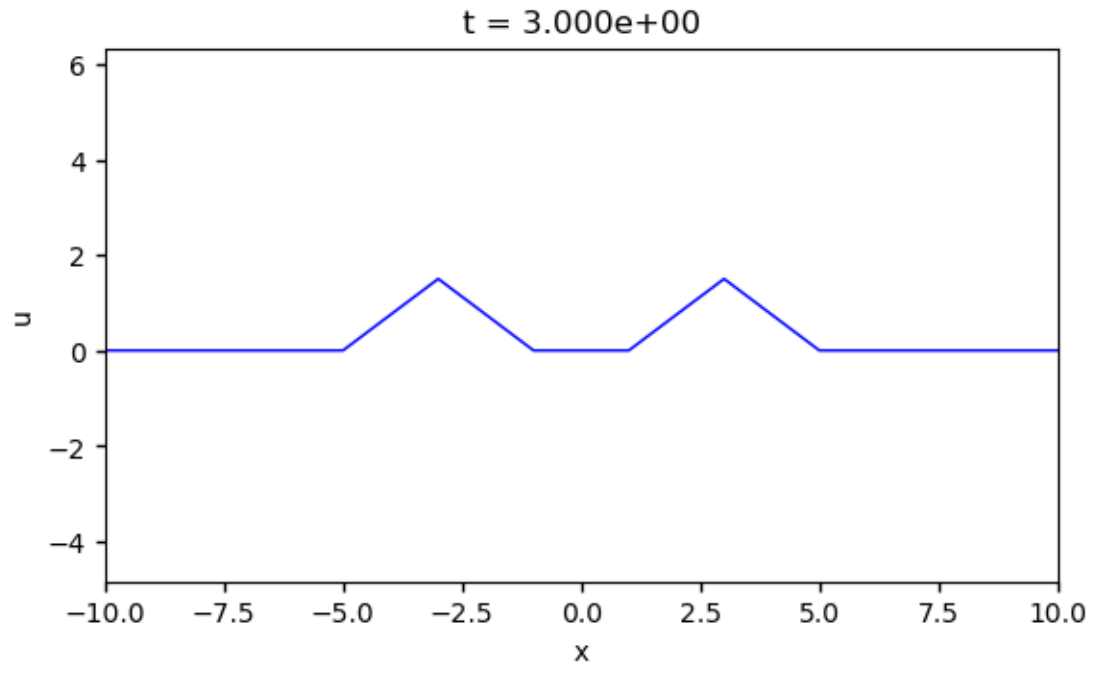
#for axis in ['top','bottom','left','right']:
# ax.spines[axis].set_linewidth(3);
# #ax.spines[axis].set_color("gold")
# ax.spines[axis].set_zorder(0)

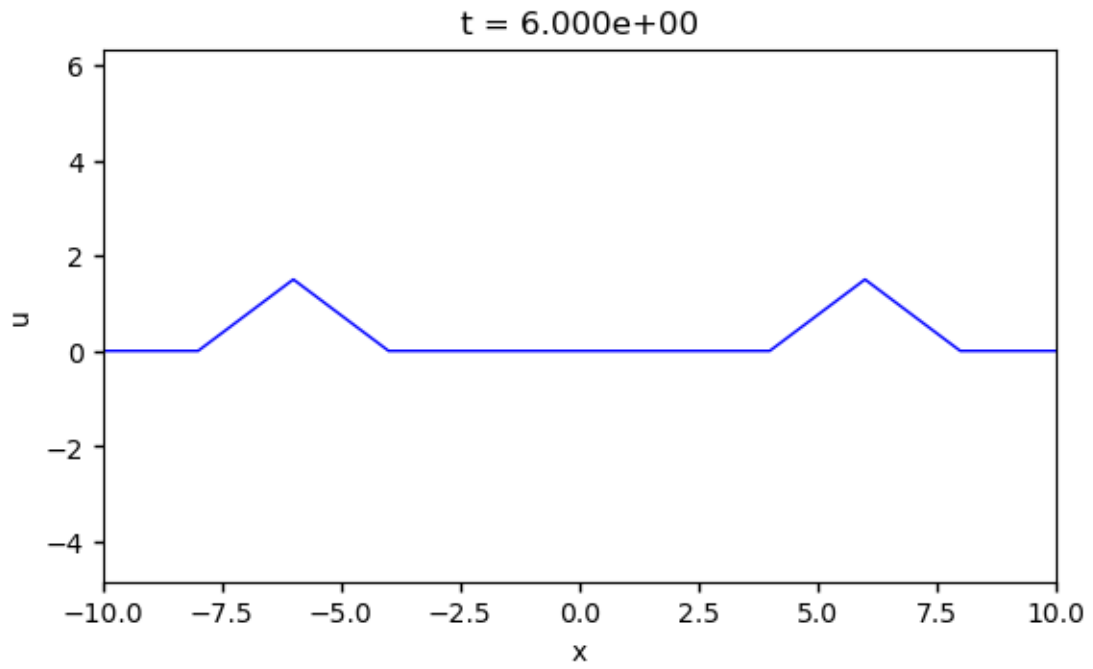
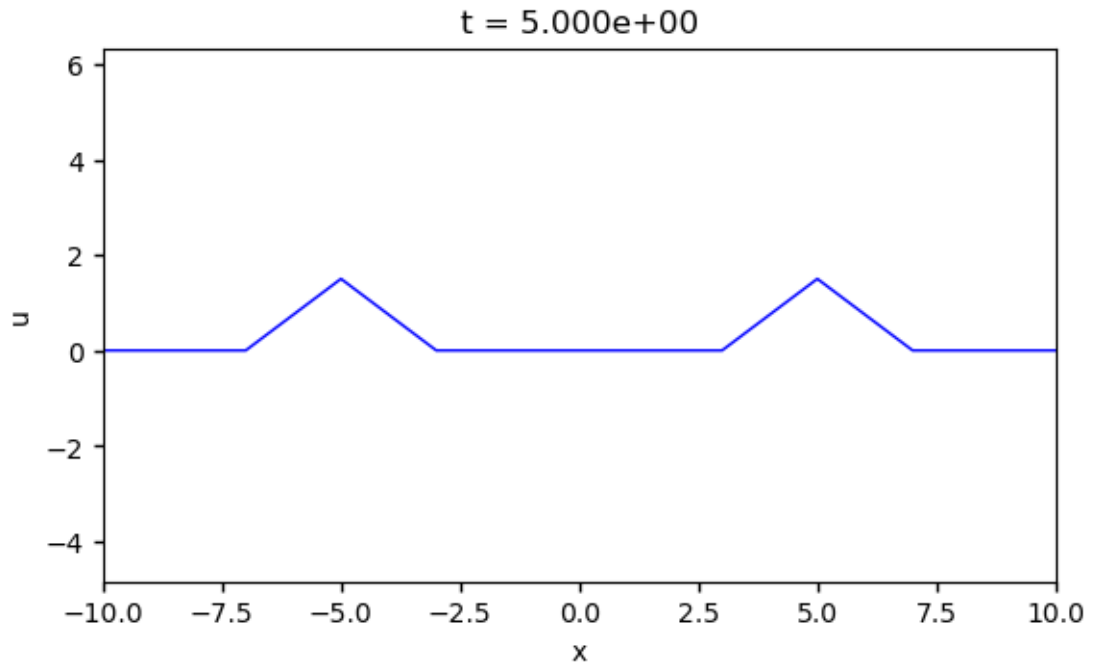
plt.draw();
```

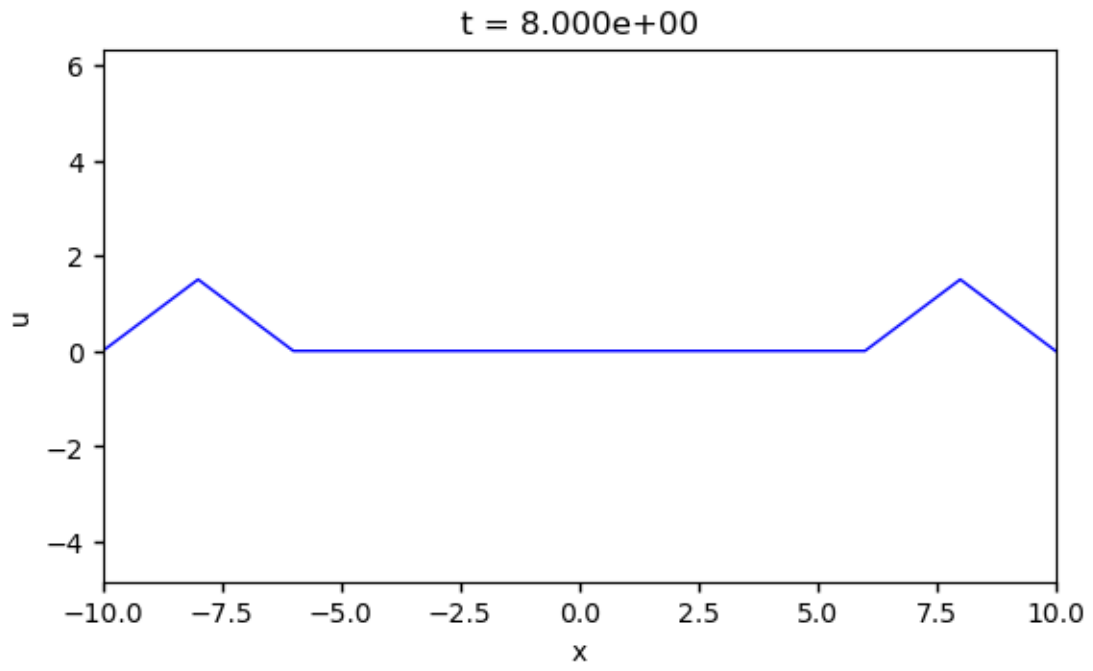
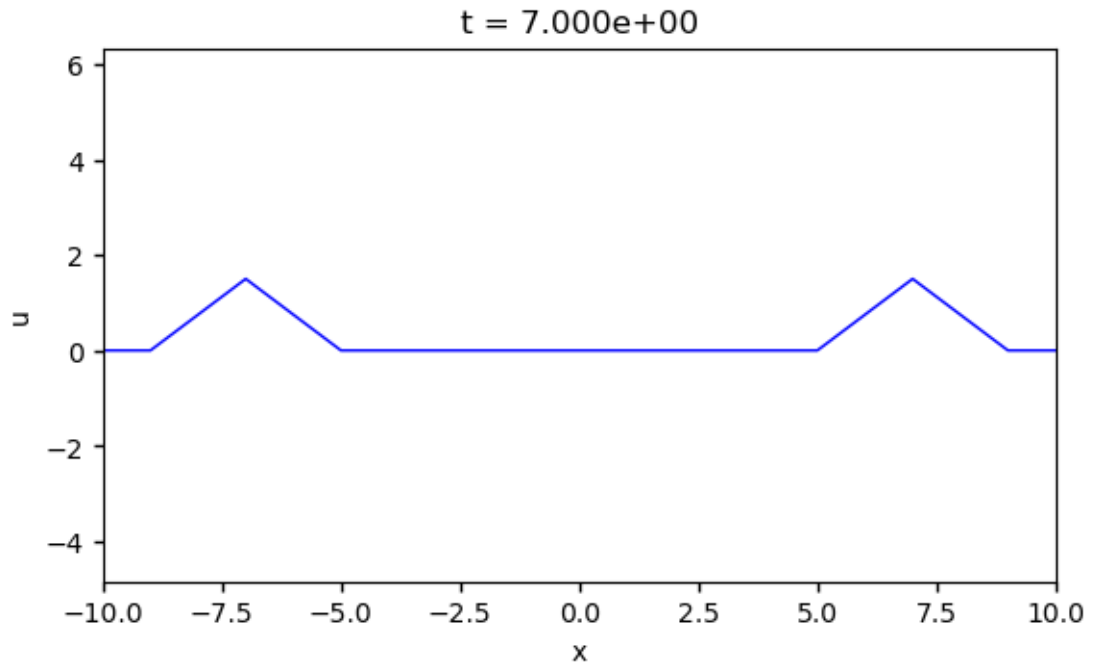
show the results

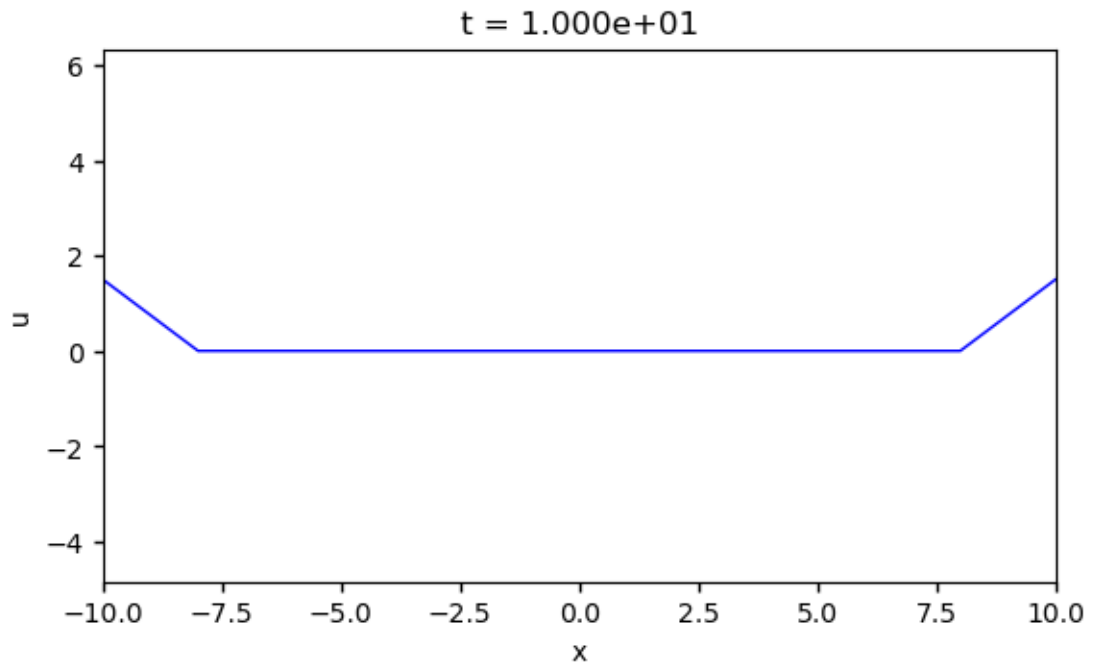
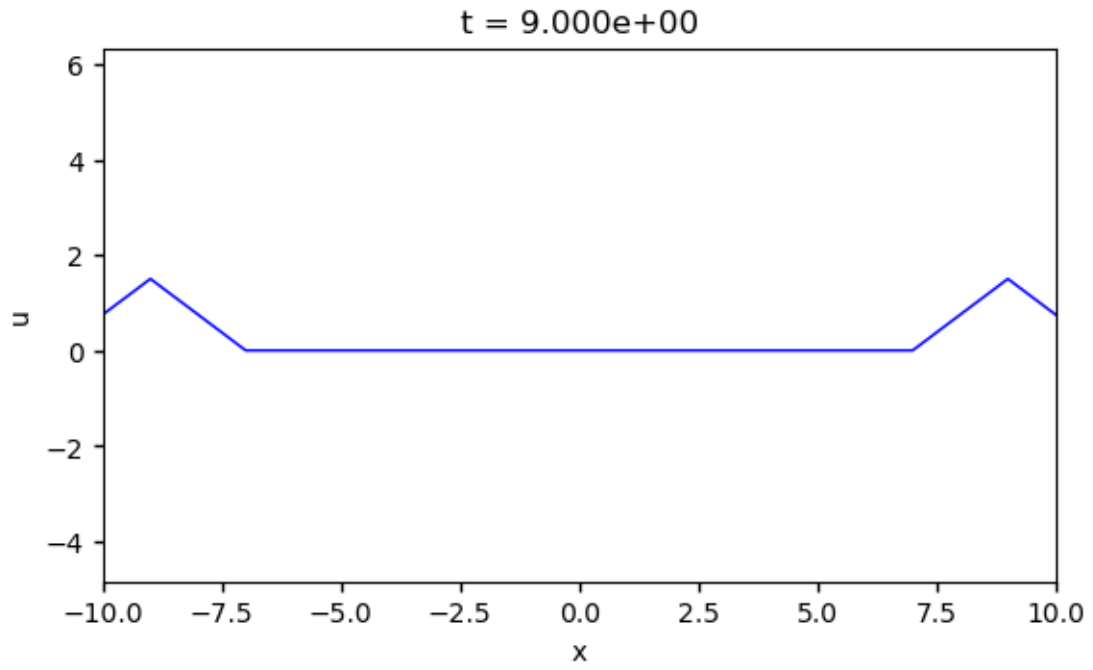


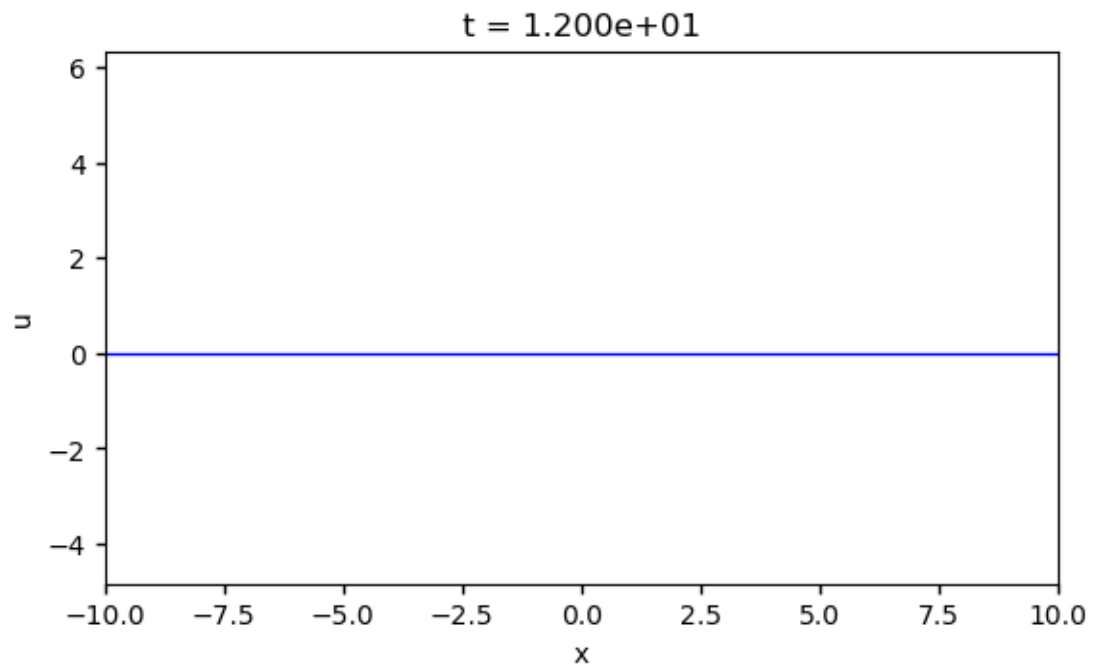
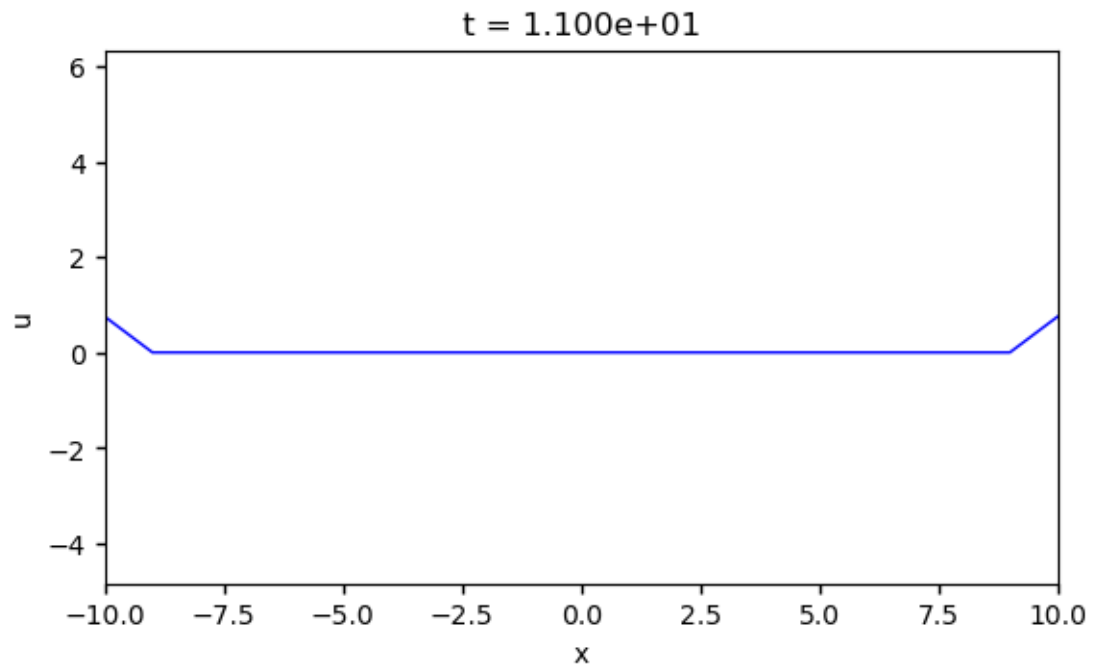


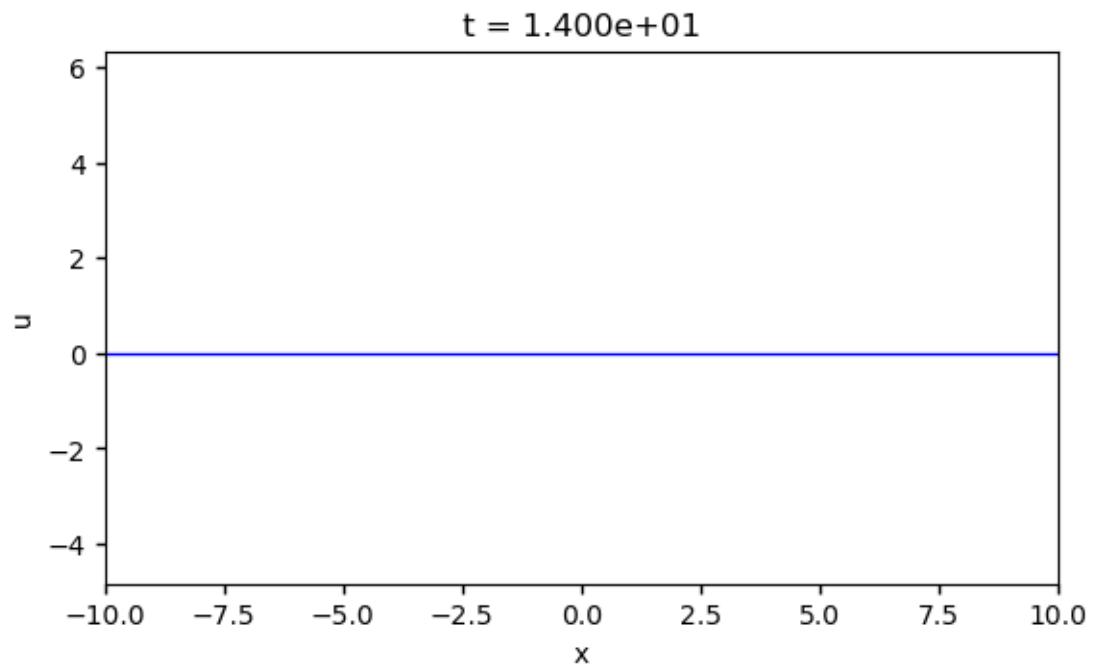
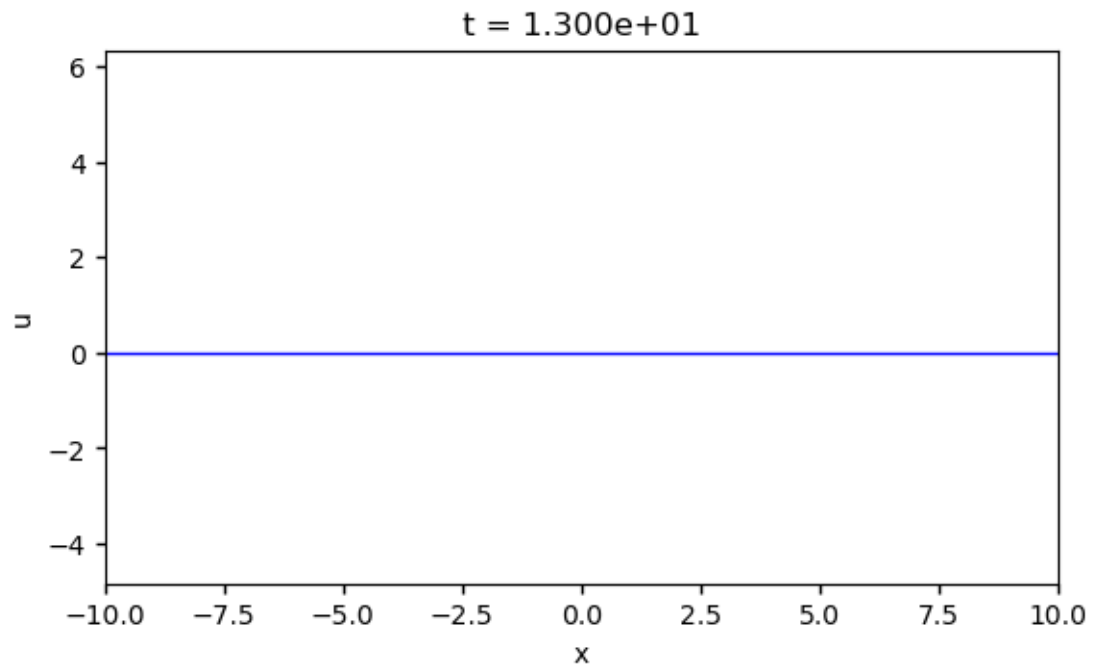












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