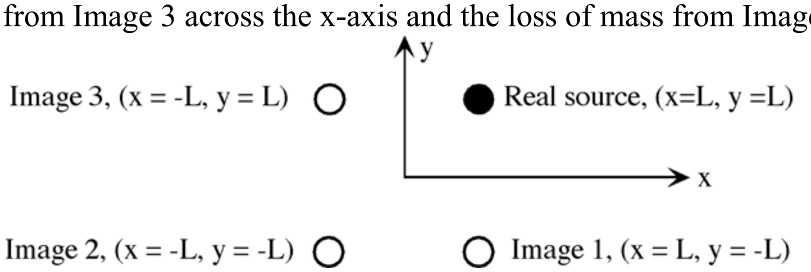
**Answer 4.1 -** Describe the concentration field inside the box from $t = 0$ to $t = L^2/D$.

**Hint 1 - When will the mass be mixed uniformly in the vertical?**
From equation 4.24 a mass released mid-way between two parallel boundaries a distance $L_Z$ apart will be mixed to a uniform concentration between those boundaries in time $t = L_Z^2/4D$, where $L_Z$ is the distance between the boundaries. The time for the concentration to become well-mixed in the vertical is then, $t = (0.01L)^2/D = 0.0001\ L^2/D$.

**Hint 2 - Estimate when the mass will reach each vertical wall in the box.**
We estimate the time that the cloud will first touch a boundary based on the standard deviation of the mass distribution. The cloud will touch the top and bottom walls when, $3\sigma = 3\sqrt{2Dt} = L$, or at the time $t = L^2/18D$. The cloud will touch the far wall when $3\sigma = 3\sqrt{2Dt} = 99L$, or at the time $t \approx 545L^2/D$.

**Hint 3 - How will each boundary impact the solution in the time $t = 0$ to $L^2/D$?**
Use the time scales determined in hint 1 and 2. Because the concentration field becomes uniform in the vertical very rapidly, within 1/10,000$^{th}$ of the time of interest, we will assume that the concentration is instantly uniform in z, i.e. $\partial C/\partial z = 0$ for all time. In the time of interest, the cloud will never reach the far walls ($545L^2/D \gg L^2/D$), so these boundaries do not impact the solution. The cloud will reach the near walls ($L^2/18D < L^2/D$), and a correction must be made to satisfy the no flux condition at these walls.

**Hint 4 - Place images sources to satisfy the no-flux boundary condition.**
Image sources are needed at the following locations. Image 2 balances the loss of mass from Image 3 across the x-axis and the loss of mass from Image 1 across the y-axis.




**Solution** - The concentration in the box is described by a superposition of two-dimensional, instantaneous, slug releases (equation 3.23) at each of the above sources.

$$C(x,y,t) = \frac{M}{L_z 4\pi Dt} \bullet$$

$$\left(\exp\left(-\frac{(x-L)^2+(y-L)^2}{4Dt}\right) + \exp\left(-\frac{(x-L)^2+(y+L)^2}{4Dt}\right) + \exp\left(-\frac{(x+L)^2+(y+L)^2}{4Dt}\right) + \exp\left(-\frac{(x+L)^2+(y-L)^2}{4Dt}\right)\right)$$

real source    image 1    image 2    image3