

Given: Velocity field $\vec{v} = ax(1+bt)\hat{i} + cy\hat{j}$, where $a=c=1s^{-1}$, $b=0.2s^{-1}$, and coordinates are measured in meters.

Plot: the streakline that passes through the point $(x_0, y_0) = (1, 1)$ during the interval $0 \leq t \leq 3s$.
Compare with the streamlines plotted through the same point at $t=0, 1,$ and $2s$

Solution:

Streakline at $t=3s$ connects particles that passed through point (x_0, y_0) at earlier times $\tau=0, 1, 2,$ and $3s$.

For a particle, $u = dx/dt$ and $v = dy/dt$
Then $u = ax(1+bt) = \frac{dx}{dt}$ and $\int_{x_0}^x \frac{dx}{x} = \int_{\tau}^t a(1+b\tau) d\tau$

$\ln \frac{x}{x_0} = a(t + \frac{b}{2}t^2)_{\tau} = a[(t-\tau) + \frac{b}{2}(t^2 - \tau^2)]$
 $x = x_0 e^{a[(t-\tau) + \frac{b}{2}(t^2 - \tau^2)]}$

Also $v = \frac{dy}{dt} = cy$, $\int_{y_0}^y \frac{dy}{y} = \int_{\tau}^t c d\tau$, $\ln \frac{y}{y_0} = c(t-\tau)$, $y = y_0 e^{c(t-\tau)}$

Substituting for $a, b, c, x_0,$ and y_0 , gives:

$x = e^{(t-\tau) + 0.1(t^2 - \tau^2)}$, $y = e^{(t-\tau)}$ ← (x, y) streakline

The streakline may be plotted by substituting values for τ in the range $0 \leq \tau \leq 3s$ as shown below.

The streamline is found (at given t) from $\frac{dy}{dx} = \frac{v}{u}$

Thus $\frac{dy}{dx} = \frac{cy}{ax(1+bt)}$ and $\int_{y_0}^y \frac{dy}{y} = \int_{x_0}^x \frac{c}{a(1+bt)} \frac{dx}{x}$

$\ln \frac{y}{y_0} = \frac{c}{a(1+bt)} \ln \frac{x}{x_0}$ or $y = y_0 \left[\frac{x}{x_0} \right]^{c/a(1+bt)}$

Substituting values for x_0, y_0, a, b, c , then

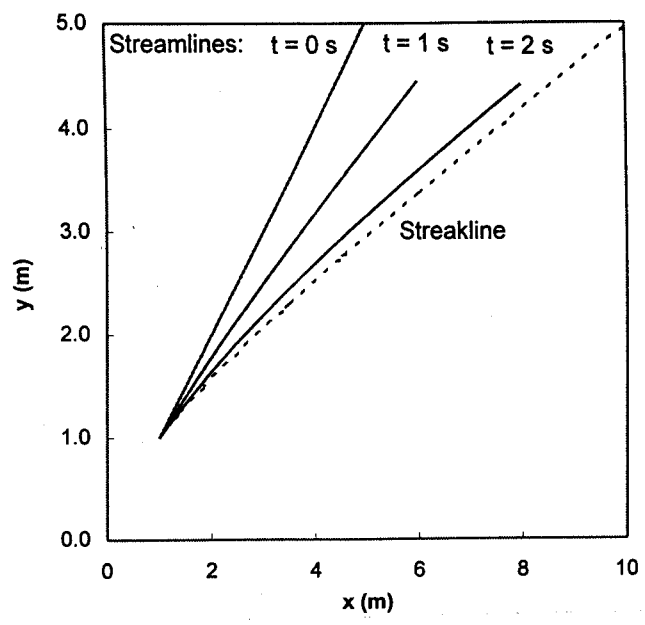
$y = x^{1/(1+0.2t)}$ or $x = y^{(1+0.2t)}$ ← streamline

At $t=0$, $x = y$
 $t=1s$, $x = y^{1.2}$
 $t=2s$, $x = y^{1.4}$

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