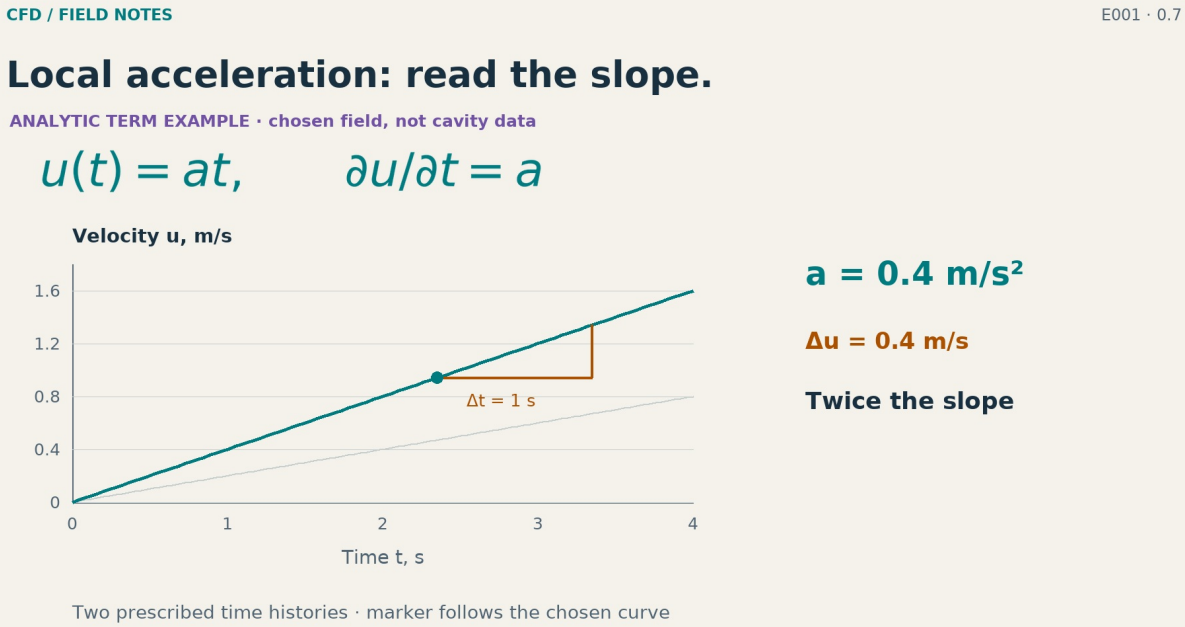
1 / A term is something you can inspect

Four small experiments before the full cavity

For a constant-density incompressible Newtonian fluid, the momentum equation used here is $\partial u/\partial t + (u\cdot\nabla)u = -\nabla p/\rho + \nu\nabla^2 u$, with $\nabla\cdot u = 0$. In this expression p is physical pressure. The installed icoFoam case stores kinematic pressure p/ρ.




```
u(t) = a*t
a = 0.2 or 0.4 m/s^2
local acceleration = du/dt = a
```

At t = 4 s, the velocities are 0.8 and 1.6 m/s. The slope doubles with a. This is a prescribed time history at a fixed location; it is not a measured cavity history. Sources: S03, S13, S19.

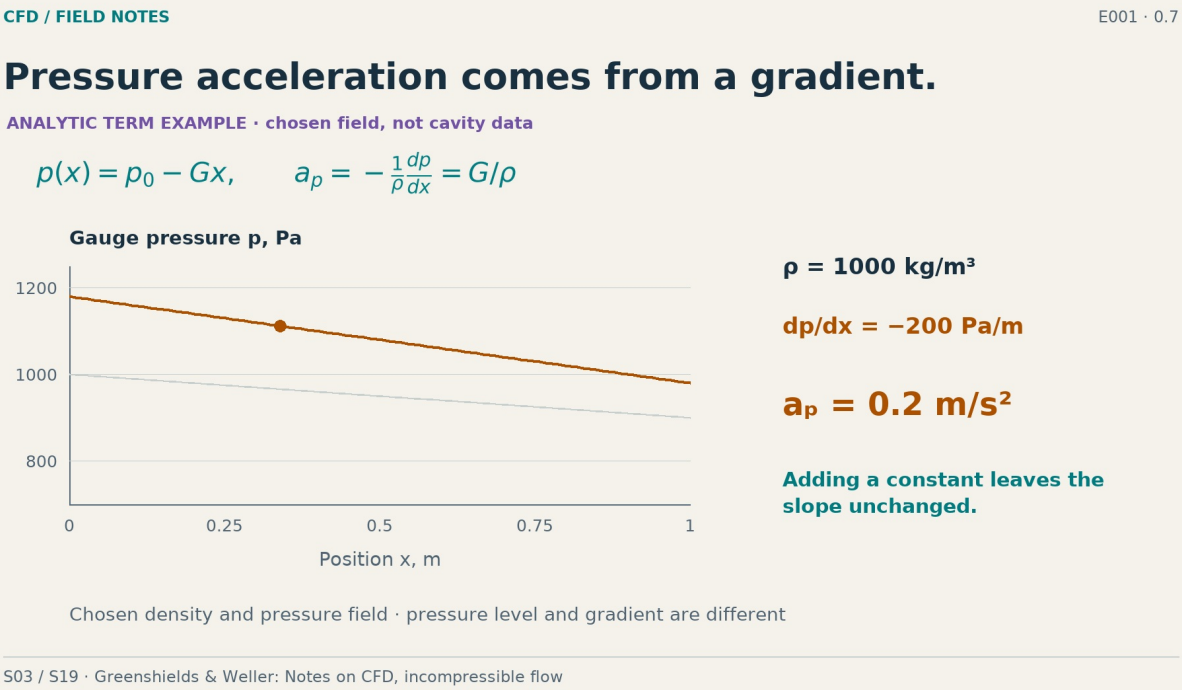
Predict before watching: if velocity is steady at every location, must acceleration along a moving path vanish?

2 / Space and pressure have slopes, too

Transport in a steady divergence-free strain field

```
u_x = k*x; u_y = -k*y
div(u) = k - k = 0
(u.grad)u_x = k^2*x
```

At x = 0.5 m, k = 0.5 s^{-1} gives a_x = 0.125 m/s^2; k = 1 s^{-1} gives 0.5 m/s^2. Doubling k doubles velocity at the same position and quadruples this acceleration. These are separate steady fields, not a simulation of k changing with time.



With p(x) = p_0 - Gx and ρ = 1000 kg/m^3, the pressure acceleration is G/ρ. G = 100 and 200 Pa/m give 0.1 and 0.2 m/s^2. Adding a constant to p changes its level but leaves this acceleration unchanged. The chosen fields illustrate terms; they are not a claim that each field independently solves the complete cavity problem. Sources: S03, S19.

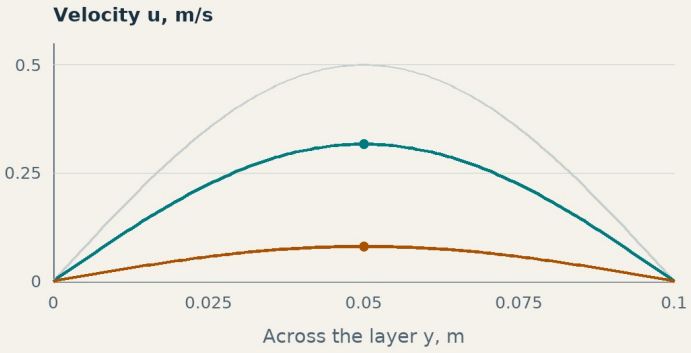
3 / Curvature and viscous smoothing

CFD / FIELD NOTES
E001 · 0.7

Curvature drives viscous smoothing.

ANALYTIC TERM EXAMPLE · chosen field, not cavity data

$$u(y,t) = Ae^{-\nu(\pi/H)^2 t}\sin(\pi y/H)$$



Replay · t = 0.46 s

A = 0.5 m/s · H = 0.1 m

ν = 0.001 m²/s

ν = 0.004 m²/s

Initial peak acceleration:

−0.493 → −1.974 m/s²

Exact shear decay · stationary walls · same initial profile for both curves

S03 / S19 · Greenshields & Weller: Notes on CFD, incompressible flow

```
u(y,t) = A*exp[-nu*(pi/H)^2*t]*sin(pi*y/H)
v = 0; A = 0.5 m/s; H = 0.1 m
du/dt = nu*d2u/dy2
```

ν / m²s⁻¹	Decay rate / s⁻¹	Initial peak acceleration / ms⁻²
0.001	0.986960	-0.493480
0.004	3.947842	-1.973921

This exact shear-decay example has stationary walls at y = 0 and H and no variation along the flow. Both profiles begin identically. At the initial peak, multiplying ν by four multiplies viscous acceleration by four. Later the profiles have different curvatures, so comparing acceleration requires their current shapes, too.

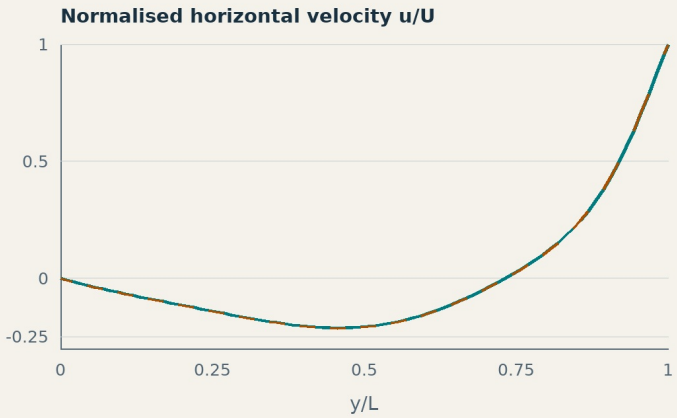
The time-labelled graphic replays this analytic decay; it is separate from the cavity run. Sources: S03, S19.

4 / Would water make the case better?

CFD / FIELD NOTES

E001 · 0.7

Water changes the scales, not the method.



Matched comparison

ν = 1 × 10⁻⁶ m²/s

U = 1 mm/s

Same Re = 100

Same t* = 10

Different physical times: 1 s and 1000 s.

Baseline: solid · water: dashed

Water property rounded for the similarity case · no heat or phase-change model

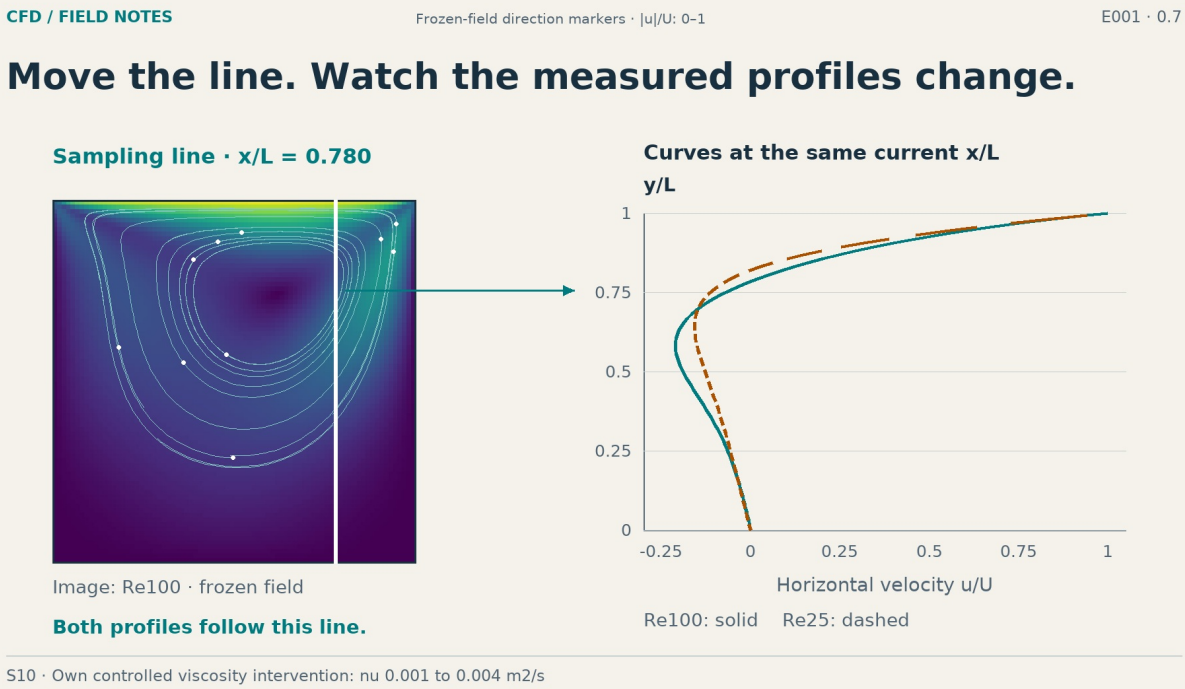
S20 / S21 · ITTC Fresh Water and Seawater Properties, Rev02 (2011), Table1 p5

Fresh water at 20 °C and 0.101325 MPa has ν = 1.0034×10⁻⁶ m²/s in ITTC Table 1. Its dynamic viscosity is about 1 mPa·s. We round ν to 10⁻⁶ m²/s for the similarity example. At unchanged U = 1 m/s and L = 0.1 m, Re would be about 100,000. That is a different problem; model suitability needs reconsideration. Source: S20.

Quantity	Baseline	Rounded water-like case
ν / m²s⁻¹	0.001	0.000001
U / m s⁻¹	1	0.001
L / m	0.1	0.1
Re	100	100
Time / s	1	1000
Δt / s	0.00025	0.25
N / steps	80 / 4000	80 / 4000

Whole-field normalised vector RMS difference: 4.864e-10. The case passes the declared 10⁻⁴ comparison screen. All fvSolution settings match the baseline: OpenFOAM checks normalised residuals, so no tolerance scaling with physical units was applied. This tests constant-property mathematical similarity, without temperature transport or phase change; it is not experimental water validation. Sources: S21, S23.

5 / The curve belongs to the line



The line is a physical sampling coordinate, not an image divider. For each current x/L, both retained N80 fields are linearly interpolated between neighbouring cell-centre columns. The plot uses that same x. The no-slip bottom and moving-lid endpoint values are added; interior lines exclude the corner discontinuity.

At the narration cue "Hold the line at the centre", x/L is fixed at 0.5 and both curves remain there. Teal is Re100, solid; amber is Re25, dashed. Colour limits and profile axes stay fixed. The displayed background is the frozen Re100 field. Direction markers show frozen-field directions; they are not simulated particle trajectories.

The local probe reverses sign under the controlled viscosity change at the specified time. That is an observed result for this case, not a universal rule that higher viscosity reverses flow. Source: S10.

The useful question is: does changing the mesh change the physical quantity that matters?

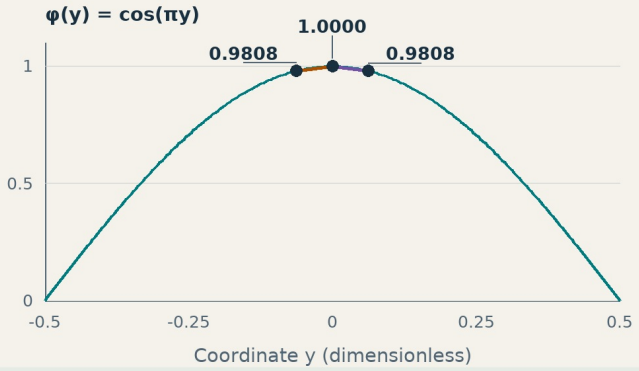
6 / Build curvature from two slopes

CFD / FIELD NOTES

E001 · 0.7

Curvature is a change of slope.

ANALYTIC TEST CURVE · not measured cavity velocity



h = 0.0625

Left slope: +0.307

Right slope: -0.307

$$\phi'' \approx \frac{m_R - m_L}{h}$$

Estimate: -9.838

Exact: −π² = −9.870

TAKEAWAY

A clean lesson about the operator, not a measurement of the cavity's error.

S11 / S19 · Analytic central second difference: cosine peak (translated sine example)

```
phi(y) = cos(pi*y); evaluate at y = 0
m_L = [phi(0) - phi(-h)] / h
m_R = [phi(h) - phi(0)] / h
D2_h phi = (m_R - m_L) / h
exact phi_second(0) = -pi^2
```

h	Left slope	Right slope	Estimate	Difference / |exact|
0.25	1.171573	-1.171573	-9.372583	5.0359%
0.0625	0.307436	-0.307436	-9.837936	0.3209%

A clean lesson about the operator, not a measurement of the cavity's error.

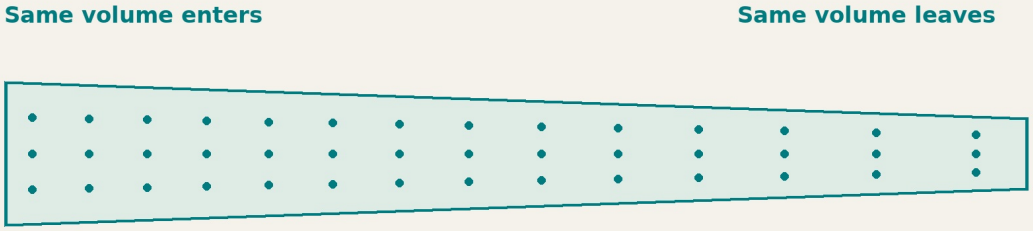
This smooth scalar interior example is a translated version of sin(πy) at y = 0.5. It does not identify the complete spatial error of the cavity scheme, including boundaries and other operators. Sources: S11, S19.

7 / Continuity gives pressure a job

CFD / FIELD NOTES

E001 · 0.7

Flow can move while volume stays balanced.



$$Q = AU = 0.2\ \mathrm{L/s}$$

Conceptual mean-flow example · equal-volume packet throughput · not CFD data

S12 · Greenshields & Weller: finite volume concept

For the conceptual steady duct, Q = AU = 0.2 L/s. A mean area of 2 cm² with U = 1 m/s and an area of 1 cm² with U = 2 m/s have the same flow rate. Equal-volume packet throughput illustrates this balance; these are illustrative numbers, not measured cavity fluxes.

In the next cell example, predicted inflow is 1 L/s and predicted outflow is 0.7 L/s. That prediction violates the incompressible volume constraint. A pressure correction alters velocity/face fluxes to reduce the imbalance. The displayed correction is conceptual, not the actual sequence or magnitude of icoFoam face-flux corrections.

Coupled means shared unknowns

The same velocity and pressure fields must satisfy momentum and continuity. PISO links them with successive corrections; coupling does not require that every unknown be solved in one monolithic matrix.

Time dependence is not URANS

This case uses transient laminar icoFoam without Reynolds-averaged turbulence closure. URANS uses unsteady Reynolds-averaged equations with turbulence modelling. Merely choosing a time step does not introduce it. Sources: S03, S12, S13, S19, S22.

Sources / 1

Complete episode sources, including mesh and numerical-reference checks, are in References_EN.md and sources.json. Existing case instructions remain in the v0.6 companion workbook. This addendum supplies the revised explanations, not a second completed walkthrough video.

S03 / Greenshields & Weller: Notes on CFD, incompressible flow

governing equations and incompressible assumptions

Open primary source

S10 / Own controlled viscosity intervention: nu 0.001 to 0.004 m2/s

Actual N80 finite-time case; input and result hashes in viscosity-case.json

S11 / Analytic central second difference: cosine peak (translated sine example)

Checked phi(y)=cos(pi*y) at y=0, equivalent to sin(pi*y) at y=0.5 under translation. This isolates a scalar interior operator, not the cavity discretisation error.

S12 / Greenshields & Weller: finite volume concept

Conceptual flux illustration; not measured face fluxes.

Open primary source

S13 / Installed OpenCFD v2606 icoFoam.C

PISO loop, pressure correction and required kinematic pressure read from the actual installed source.

Sources / 2

S19 / Own checked analytic term and continuity examples

Explicit functions and coefficients in review-math.json; labelled illustrations, not cavity measurements.

S20 / ITTC Fresh Water and Seawater Properties, Rev02 (2011), Table1 p5

Fresh water20C at0.101325MPa: nu1.0034e-6m2/s; rounded1e-6 used in the similarity case, not exact thermophysical modelling.

Open primary source

S21 / Own matched-Re water-like N80 case

nu=1e-6, U=0.001m/s, t=1000s, dt=0.25s. fvSolution matches baseline exactly; installed solver residual normalisation inspected. Actual field comparison; earlier tighter-tolerance attempt retained separately.

S22 / OpenFOAM solver and RAS documentation; installed icoFoam source

Transient incompressible laminar icoFoam; no Reynolds-averaged turbulence closure in this case. Checked against installed v2606 source, with official published solver source as a public reference.

Open primary source

S23 / OpenCFD: residual normalisation and installed lduMatrix solver source

Default residual norm and installed v2606 smoothSolver/lduMatrix normalisation inspected. Tolerance is applied to the normalised residual, not a velocity/pressure unit.

Open primary source