Mass-Conservation Tests

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1 PorousFlowFluidMass postprocessor

1.1 Single-phase, single-component

The total fluid mass of species sp within a volume V is

$$\int_V \phi \sum_{\mathrm{ph}} \rho_{\mathrm{ph}} S_{\mathrm{ph}} \chi_{\mathrm{ph}}^{\mathrm{sp}} . \tag{1.1}$$

It must be checked that MOOSE calculates this correctly in order that mass-balances be correct, and also because this quantity is used in a number of other tests

A 1D model with $-1 \leq x \leq 1$, and with three elements of size 1 is created with the following properties:

Constant fluid bulk modulus	1 Pa
Fluid density at zero pressure	1 kg.m^{-3}
Van Genuchten m	0.5
Van Genuchten α	1 Pa^{-1}
Porosity	0.1

The porepressure is set at $P = x$.

Recall that in PorousFlow, mass is lumped to the nodes. Therefore, the integral above is evaluated at the nodes, and a sum of the results is outputted as the PorousFlowFluidMass postprocessor. Using the properties given above, this yields:

x	p	Density	Saturation	Nodal mass
-1	-1	0.367879441	0.707106781	0.008671002
-0.333333333	-0.333333333	0.716531311	0.948683298	0.02265871
-0.333333333	-0.333333333	0.716531311	0.948683298	0.02265871
0.333333333	0.333333333	1.395612425	1	0.046520414
0.333333333	0.333333333	1.395612425	1	0.046520414
1	1	2.718281828	1	0.090609394
			Total	0.237638643

MOOSE also gives the total mass as 0.237638643 kg. This test is part of the automatic test suite that is run every time the code is updated.

1.2 Single-phase, two-components

The same test as Section 1.1 is run but with two components. The mass fraction is fixed at

$$\chi^{\mathrm{sp}=0}_{\mathrm{ph}=0} = x^2 \ . \tag{1.2}$$

x	p	Density	Saturation	$\chi^{\mathrm{sp}=0}_{\mathrm{ph}=0}$	Nodal mass$_{\mathrm{sp}=0}$	Nodal mass$_{\mathrm{sp}=1}$
-1	-1	0.367879441	0.707106781	1	0.008671	0
-0.333333333	-0.333333333	0.716531311	0.948683298	0.111111	0.00251763	0.02014108
-0.333333333	-0.333333333	0.716531311	0.948683298	0.111111	0.00251763	0.02014108
0.333333333	0.333333333	1.395612425	1	0.111111	0.00516893	0.04135148
0.333333333	0.333333333	1.395612425	1	0.111111	0.00516893	0.04135148
1	1	2.718281828	1	1	0.09060939	0
				Total	0.11465353	0.12298511

MOOSE produces the expected answer.

1.3 Two-phase, two-components

A 1D model with two elements from $0 \leq x \leq 1$ is created, with two phases (0 and 1), and two fluid components (0 and 1). The phase densities are calculated using a constant bulk modulus fluid with bulk modulus of 1 Pa. The density at zero pressure is 1 kg m-3 for phase 0, and 0.1 kg m^{-3} for phase 1. The porepressure of phase 0 is held fixed at 1 Pa, and a constant capillary pressure of 0 is specified so that the pressure of phase 1 is also 1 Pa. This results in phase densities of $e = 2.71812818...$ kg m^{-3} for phase 0, and 0.271812818... kg m^{-3} for phase 1.

Saturation of phase 1 varies linearly as $1 - x$, while porosity is 0.1 throughout. The mass fraction of species 0 in fluid phase 0 is specified as 0.3, while the mass fraction of species 0 in phase 1 is 0.55. It is simple to calculate the total mass of each component in each phase using Eq. (1.1), the results of which are

Species	Phase	Total mass (Eq. (1.1))	Total mass (MOOSE)
0	0	0.04077423	0.04077423
0	1	0.007475275	0.007475275
0	all	0.04824950	0.04824950
1	0	0.09513986	0.09513986
1	1	0.006116134	0.006116134
1	all	0.10125560	0.1012560