The Same Water Can Be Stopped and Passed Because Pore Radius Enters the Two Transports at Different Powers

— shrinking the pore radius tenfold cuts viscous liquid flow to **0.010000** while vapour, leaving by diffusion, stays at **1.000000**, a gap of **100.000000** — the separator is the power at which the radius enters — [Paper 722]

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— *From thinking to syncing.* —

Abstract

There are membranes that stop water as a liquid and pass it as a vapour. Not magic: the pore radius enters the two transports differently.That difference is counted as the response of each to the same change in radius.No new theorem or law is claimed. First, liquid is stopped by capillary pressure——past a contact angle of 90 degrees water cannot enter of its own accord, and entering takes pressure (Section 2). **Second, that pressure is inversely proportional to the radius——a head of 7.438411 m at 1 μm, 74.384109 m at 0.1 μm and 148.768217 m at 0.05 μm** (Section 2). **Third, the vapour side does not depend on the radius——leaving by diffusion, its flow is set by porosity and thickness and shows no difference over a factor of 40 in radius** (Section 3). **Fourth, and this is the core. The two answer the same change in radius at different powers——reduce it tenfold and viscous liquid flow falls to 0.010000 while vapour stays at 1.000000, a gap of 100.000000** (Section 3). **Fifth, so one radius can satisfy two requirements at once——the water-entry pressure alone rises by 10.000000, and breathability does not fall** (Section 3). **Sixth, the separator is the power at which the pore radius enters——one and the same pore acts on two transports at different orders** (Section 4). **Keywords**: Young-Laplace equation, contact angle, water-entry pressure, vapour transmission, power of the pore radius, Knudsen regime.

Scope of this paper (scope note): **No new theorem or law is claimed——the Young-Laplace equation, the sign of capillary pressure set by contact angle, and diffusive transport through porous membranes are all standard (Young 1805, de Gennes 1985).Knudsen diffusion is not treated——a radius of 0.1 µm is the same order as the mean free path in air, so the vapour-side estimate using a continuum diffusion coefficient breaks down there; this limit is stated in Section 3.No real membrane is claimed——the breathability of microporous or nonporous hydrophilic membranes is not treated.Contamination is not treated——the fall in contact angle from surfactants or soiling is not treated; that it can be the main cause of failure in practice is only mentioned.No precision is claimed for representative values——the surface tension of 0.0728 N/m, contact angle of 120 degrees, porosity of 0.8, thickness of 30 µm and the diffusion coefficient are order-of-magnitude values.Sorption is not treated——transport by condensation or by the fibre's own sorption is not treated.Relation to earlier papers**: **Paper 309 showed that the length dividing gravity from surface tension is nobody's size——its scope note stated that contact angle would not be treated and the calculation performed at $\cos\theta = 1$, complete wetting, leaving the seat open. Here we stand where that contact angle changes sign: one Young-Laplace equation lifts when cos is positive and pushes back when it is negative.**What is added is **putting the water-entry pressure at a head of 74.384109 m**, **confirming the vapour side to be radius-independent over a factor of 40**, **putting the gap in response to one tenfold reduction at 100.000000**, **stating the Knudsen regime as a limit**, and **placing the separator on the power at which the radius enters**.

1. Notation and the Question

Setting: **for a pore of radius r, the pressure needed for liquid to enter and the diffusive flow of vapour are written separately.**

$$\Delta p = \frac{2\gamma|\cos\theta|}{r}, \qquad P_{\text{vapour}} = \frac{D\,\phi}{L}, \qquad Q_{\text{viscous}} \propto r^2$$

ϕ is porosity and L thickness. A surface tension of 0.0728 N/m, a contact angle of 120 degrees (cos being -0.500000), a porosity of 0.8 and a thickness of 30 µm are taken as representative.

Question: **how can one pore size satisfy both requirements, stopping liquid and passing vapour?**

2. Liquid Is Stopped by Capillary Pressure

Computation 2.1: **the pressure needed for water to enter was derived for each pore radius.**

radius	pressure	atmospheres	head of water
1.00 µm	72800 Pa	0.718480	7.438411 m
0.50 µm	145600 Pa	1.436960	14.876822 m
0.10 µm	728000 Pa	7.184801	74.384109 m
0.05 µm	1456000 Pa	14.369603	148.768217 m

Observation 2.2

the sign settles the direction.Past 90 degrees the cosine turns negative, so the same equation pushes back instead of lifting——on a completely wetting surface the same equation becomes a suction of $2\gamma/r$, the ratio agreeing at 1.000000.

Observation 2.3

so a narrower pore stops it harder.Reducing the radius tenfold raises the required pressure by exactly 10.000000——a head of 74.384109 m at 0.1 µm is ample against rain and against water pressure.

Observation 2.4

but the margin leans on the contact angle.As the angle approaches 90 degrees the capillary pressure tends to zero——if soiling or surfactant moves the cosine toward zero, the water resistance is lost with the pore size unchanged.

3. The Vapour Side Does Not Depend on the Radius

Computation 3.1: the diffusive flow of vapour and the viscous flow of liquid were set side by side against the same change in radius.

quantity	on reducing the radius tenfold	how the radius enters
water-entry pressure	10.000000	r^{-1}
vapour transmission	1.000000	r^{0}
viscous liquid flow	0.010000	r^{2}

Observation 3.2

this is the core: three quantities answer the same radius at different powers.The gap between vapour and liquid opens by 100.000000——so the single act of narrowing the pore cuts only one of them.

Observation 3.3

the vapour side is radius-independent because it leaves by a different route.Its flow is set by porosity and thickness, and varying the radius over a factor of 40 makes no difference——what matters is the total area and length of the path, not its narrowness.

Observation 3.4

so the design splits into two quantities.Water resistance is set by the radius, breathability by porosity and thickness——one knob need not chase both.

Observation 3.5

this estimate has a limit that bites.A radius of 0.1 µm is the same order as the mean free path in air, so the vapour-side value from a continuum diffusion coefficient breaks down there——in the Knudsen regime the vapour side begins to depend on the radius too, so reading the exponent as zero holds only while the pores are large enough.

4. The Separator

Observation 4.1

the separator is the power at which the pore radius enters.Water-entry pressure goes as r^{-1}, vapour as r^{0}, viscous liquid flow as r^{2}——the phrase “the same pore” hides three different dependences.

Observation 4.2

beside Paper 309.Paper 309 showed the length dividing gravity from surface tension to be nobody’s size, stating that contact angle would not be treated and calculating at $\cos\theta = 1$——here we stand where that contact angle changes sign: one equation lifts when the cosine is positive and pushes back when it is negative.

Observation 4.3

what is not said.Knudsen diffusion, real membranes, contamination and sorption are not treated, and five quantities are held fixed as representative——what is shown is that the exponent of the response to one radius differs from transport to transport.

5. Roll Call and Closing

1. **cos is -0.500000** (Section 1): **a contact angle of 120 degrees.**
2. **7.438411 m of head at 1 µm** (Computation 2.1): **it stops.**
3. **74.384109 m at 0.1 µm** (Computation 2.1): **ample margin.**
4. **148.768217 m at 0.05 µm** (Computation 2.1): **double again.**
5. **7.184801 atmospheres** (Computation 2.1): **at 0.1 µm.**
6. **ratio 1.000000 when fully wetting** (Observation 2.2): **the same equation.**
7. **water-entry pressure 10.000000** (Computation 3.1): **r^{-1}.**
8. **vapour 1.000000** (Computation 3.1): **r^{0}.**
9. **viscous flow 0.010000** (Computation 3.1): **r^{2}; the core.**
10. **at what power the radius enters** (Observation 4.1): **the separator; Paper 309.**

Closing: **The same water can be stopped and passed because pore radius enters the two transports at different powers.Past a contact angle of 90 degrees the cosine turns negative, so water cannot enter of its own accord and entering takes a pressure above the capillary pressure——with a surface tension of 0.0728 N/m and a contact angle of 120 degrees, a radius of 1 µm withstands a head of 7.438411 m, 0.1 µm withstands 74.384109 m and 0.05 µm withstands 148.768217 m, a tenfold reduction giving exactly 10.000000.Vapour, by contrast, leaves by diffusion, so its flow is set by porosity and thickness and does not move when the radius is varied over a factor of 40——so for the same tenfold reduction, viscous liquid flow falls to 0.010000 while vapour stays at 1.000000, a gap of 100.000000 .The single act of narrowing the pore cuts only one of them, so water resistance can be set by the radius and breathability by porosity and thickness, separately.But the margin leans on the contact angle——if soiling or surfactant moves the cosine toward zero, the water resistance is lost with the pore size unchanged.And a radius of 0.1 µm is the same order as the mean free path in air, so the vapour-side value from a continuum diffusion coefficient breaks down there——in the Knudsen regime the vapour side begins to depend on the radius too, so the zeroth power holds only while the pores are large enough.The separator is the power at which the pore radius enters.Placed among the earlier papers——Paper 309 stated that contact angle would not be treated and calculated at complete wetting; here we stand where the cosine is negative.To be honest——Knudsen diffusion, real membranes and contamination are not treated, and five quantities are held fixed as representative.**

References

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