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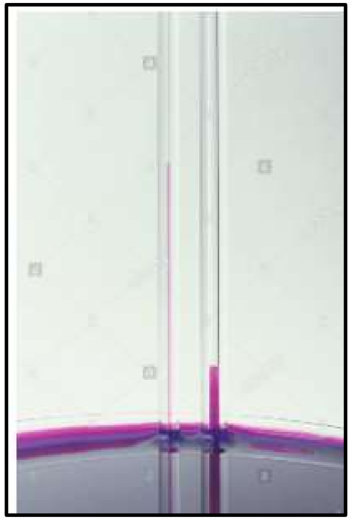
Capillary Forces

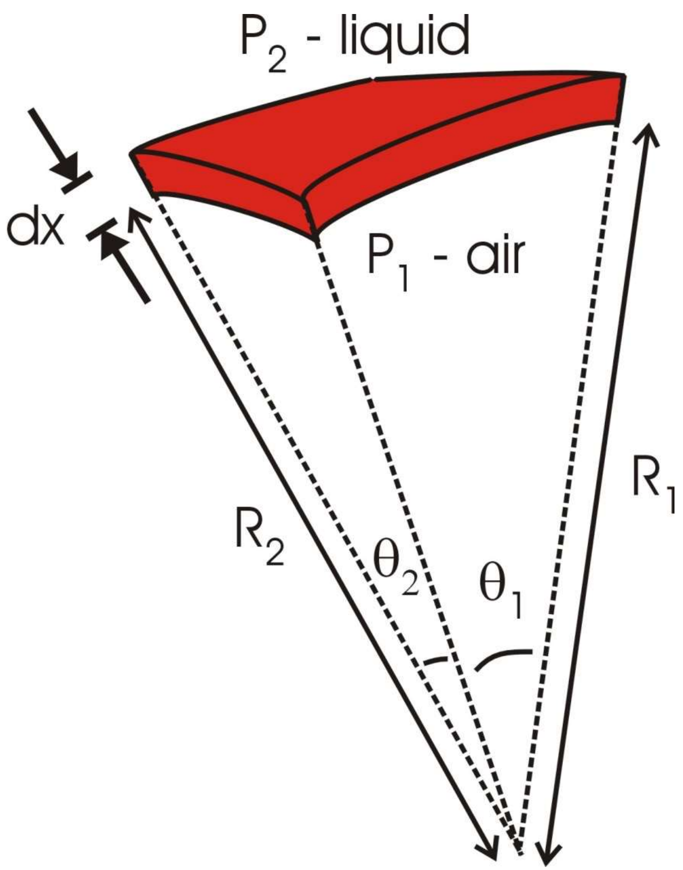
Force & function at the nanoscale

Curved Liquid Interfaces

Liquid interfaces nearly always involve curvature



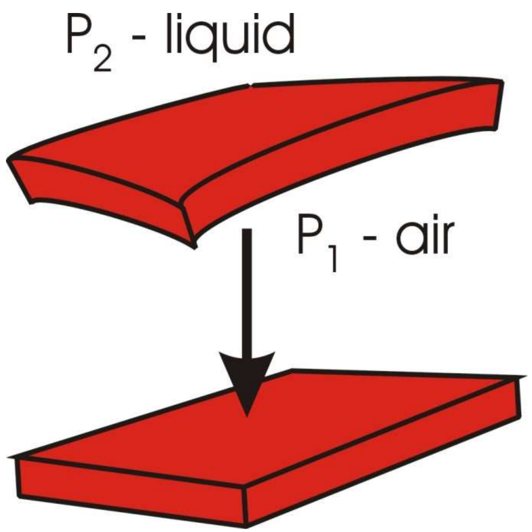
Pressure difference across a liquid vapour interface



In the last lecture we considered the energy associated with creating flat surfaces. What happens if a surface between two liquids (or a liquid and air) becomes curved?

Capillary pressure

There is a pressure difference across a curved liquid interface which acts to try to reduce the area of the interface. This is called the **Capillary Pressure**



$$\Delta P = P_1 - P_2 = \gamma \left(\frac{1}{R_1} + \frac{1}{R_2} \right)$$

γ is surface energy/tension (Jm^{-2})

R_1 and R_2 are principal radii of curvature in two orthogonal directions

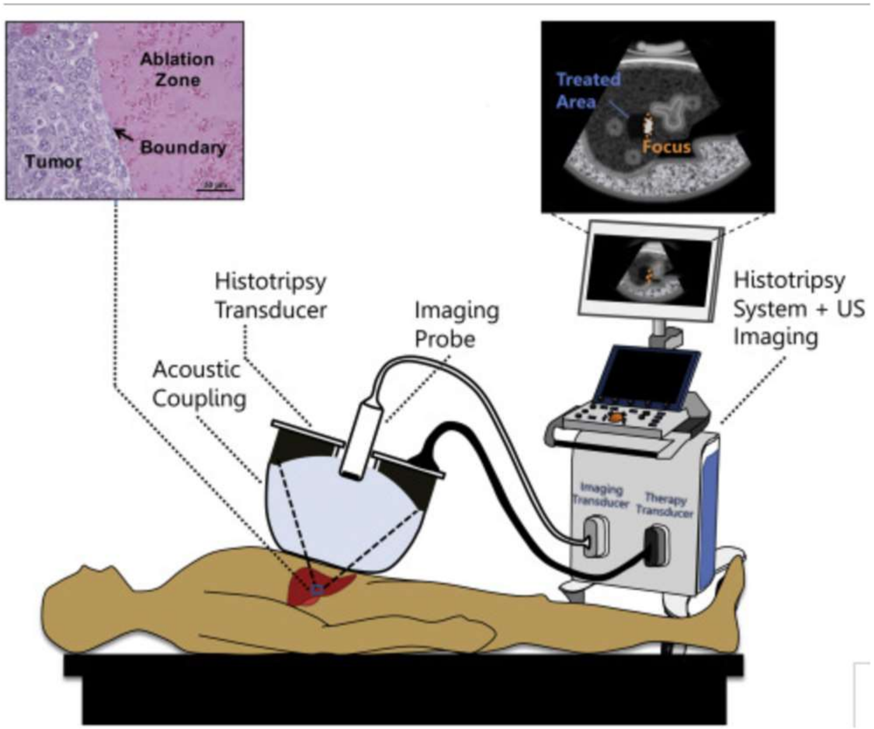
Problem 8.2 – The spherical bubble

Calculate the capillary pressure for a spherical air bubble of radius 10 μm in water γ=72 mJm^{-2}

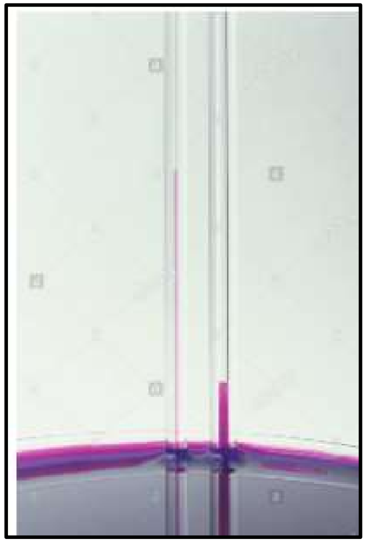
$$\Delta P = \gamma\left(\frac{1}{R_1}+\frac{1}{R_2}\right)$$

High pressure nanobubbles

Using nanobubbles to treat tumours



Capillary Rise



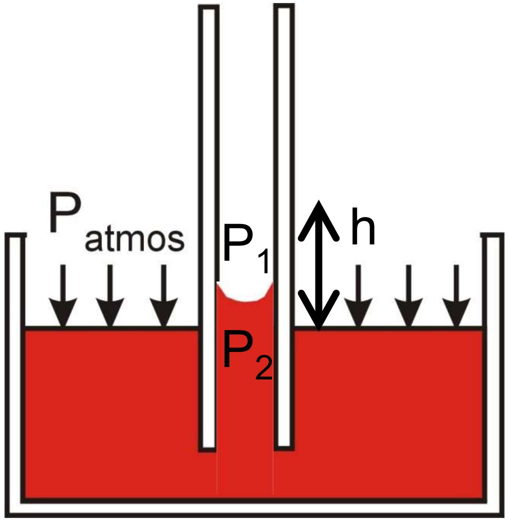
When a fine capillary is placed inside a liquid, a curved liquid meniscus forms.

The resulting pressure drop across the interface causes the fluid to be drawn up inside the capillary

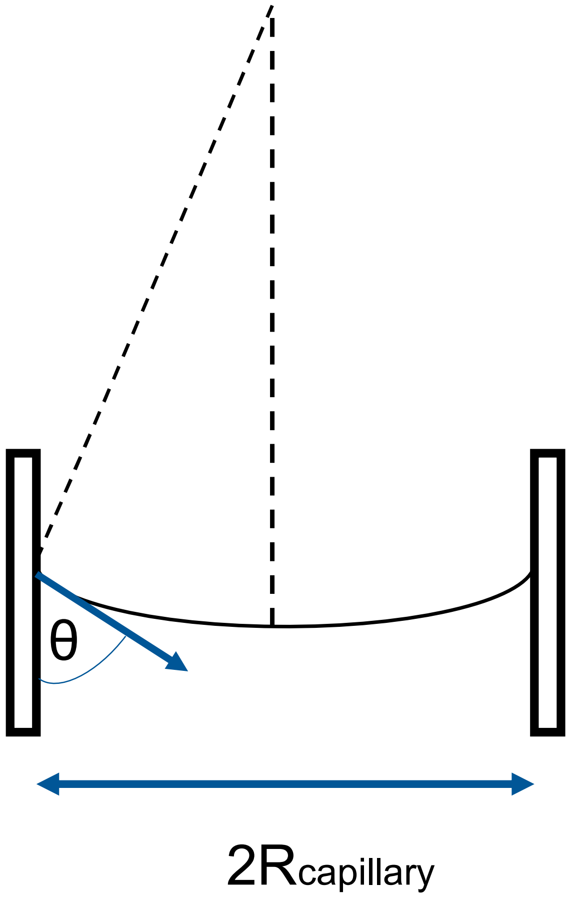
This is referred to as **capillary rise**

$P_2 > P_1$ $(= P_{atmos})$

pressure difference between surface of reservoir and P_2 forces fluid up the column

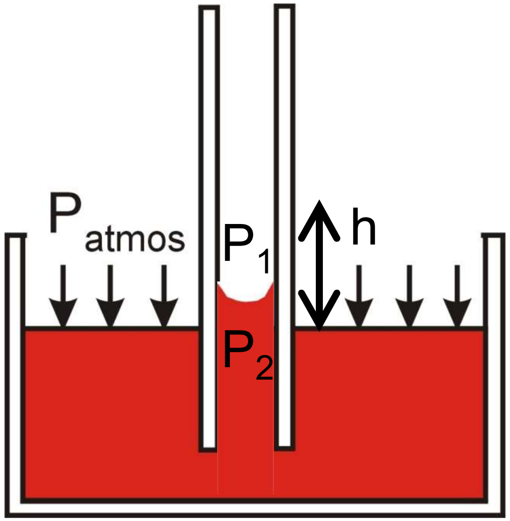


What's the pressure drop for a capillary of radius R?



$$\Delta P = \gamma\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

How high will liquid rise in a capillary?



Balance the pressure due to the weight of fluid against the capillary pressure

$$h = \frac{2\gamma cos\theta}{\rho g R}$$

Question: What will happen if you dip a capillary in liquid mercury?

Settling arguments with your landlord

You have a ground floor bedroom and you notice that there is some mildew growing on the wall near to the floor. It continues up the wall to a height of about 1m and then stops.

Your landlord insists that it is forming because you should spend more money, and heat the house properly but you think it is because

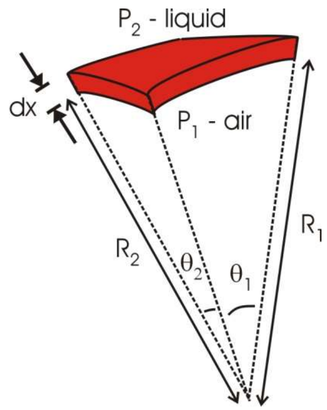
How do you prove that it is your landlord being tight? He hasn't fixed the dampcourse layer to prevent rising damp.

Brick has a continuous pore network ~ 30μm in diameter. It wets very well with contact angle ~ 0°. γ=72mJm^{-2} Density of water = 1gcm^{-3}

Summary of key concepts

Capillary pressure due to a curved liquid interface

$$P = \gamma\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$



Capillary pressure is responsible for phenomenon of capillary rise

$$h = \frac{2\gamma cos\theta}{\rho g R}$$