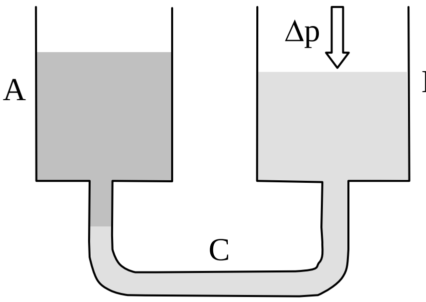
FLUIDS I
Example sheet 1: Static Fluids

1. Find the pressure at a depth of 10metres below the surface of a lake if the pressure at the surface is 101,300 Pa.
[Ans: $1.994 x 10^5$Pa]

2. a) Calculate the height of the mercury column in a barometer at an atmospheric pressure of $1.013 x 10^5$ N/m^2 (the density of mercury is 13560 kg/m^3 and the vapour pressure at the top of the column is negligible).
b) What would happen to the height of the mercury column if the barometer tube was curled and the diameter increased with height?
c) What would the height of the column be if the mercury were replaced by alcohol (density is 790 kg/m^3 and the vapour pressure is $5.7 x 10^3$ N/m^2)
[Ans: a) 0.762m, b) 12.336m]

3. A monometer consistes of two tubes A and B, with vertical axes and uniform cross-sectional areas of 500 mm^2 and 800 mm^2 respectively; connected by a U-tube, C, of uniform cross-sectional area 70 mm^2 . Tube A contains liquid of density 800 kg/m^3, tube B contains one of density 900 kg/m^3. If both fluids are initially in static equilibrium, what additional pressure applied to the surface of the fluid in tube B, would cause the interface between both fluids to rise by 0.06m in the tube C?
[Ans: 171.13 N/m^2]



4. A spherical air bubble rises in water. At a depth of 9m its diameter is 4mm. What is its diameter just as it reaches the free surface where the atmospheric pressure is 1.013 bar. (We shall assume that surface tension is negligible and that heat transfer with the water keeps the air in the bubble at a constant temperature).
[Ans: 4.93 mm]

5. When considering large vertical displacements in the atmosphere we must allow for the variation in the density. The troposphere (first 10km) has an approximately linear decrease in temperature with height so that: $\frac{dT}{dz} = -\lambda$, where λ is a constant. Use this relation together with the equation for a perfect gas ($p = \rho RT$) and the hydrostatic equation for variable density fluids to show that the pressure at a height z is given by

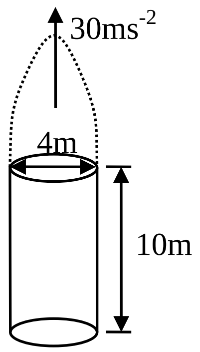
$$p = p_{sl}\left(1 - \lambda z / T_{sl}\right)^{\frac{g}{R\lambda}}$$

where the subscript "sl" represents the reference values at $z=0$ (sea level).

Hint. Rearrange and integrate to get the intermediate relationship: $\int_{p_{sl}}^{p} \frac{dp}{p} = \frac{g}{R\lambda} \int_{T_{sl}}^{T} \frac{dT}{T}$

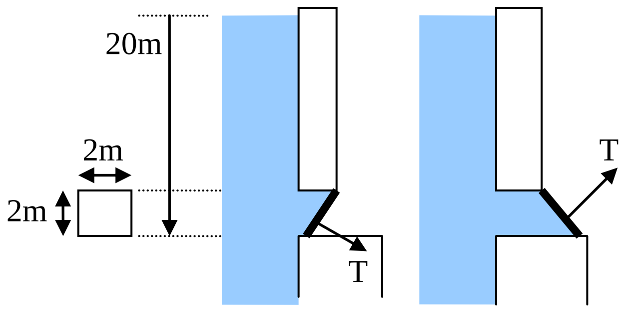
6. A spherical, helium filled, balloon of diameter 800mm is to be used to carry meteorological instruments to a height of 6000m above sea level. The instruments have a mass of 60g and negligible volume while the balloon material has a mass of 100g. Assuming that the balloon does not expand and that the atmospheric temperature decreases at a uniform rate of 0.0065^{o}K/m, use the solution from question 5 above to determine the mass of helium required. Atmospheric pressure and temperature at sea level can be taken as $1.013 x 10^5$Pa and 288.15^{o}K, while for air R=287 J/kg K
[Ans: 0.0168kg]

7. A rocket with a full cylindrical liquid fuel cell (base diameter 4m and height 10m) accelerates vertically at a rate of 30ms^{-2}. If the specific gravity of the propellant is 0.91, find the gauge pressure and hydrostatic thrust at the base of the fuel cell.
[Ans: $3.623 x 10^5$N/m^2, $4.552 x 10^6$N]



8. An engineer considers two possible installations of a rectangular sluice gate in the 2m square opening of a dam. The bottom of each gate is 20m below the surface of the water. The gates are each at an angle of 30^o to the vertical; the first facing upward, the second facing downward. Find the normal thrust, and the line of action of the thrust in terms of the water depth, on the gate in each case.

[Ans: 8.609×10^5N, 8.609×10^5N, 19.018m]



9. Consider a vehicle with a square fuel tank, of dimension 1m in each, direction half full of fuel with S.G=0.85. The vehicle travels around a bend in the road such that a steady acceleration of exactly $9.81 m/s^2$ is applied approximately uniformly away from the centre of radius of the bend.

a) Calculate the moment, taken clockwise about the point A shown, the fuel exerts on the fuel tank.
b) Calculate the same moment if the fuel surface were constrained not to move
c) Calculate the moment about A when the vehicle is moving in a straight line and at a constant speed.

[Ans: a) 0Nm, b) -1042.3Nm, c) -2084.6Nm]