# PHY250 HOMEWORK 1

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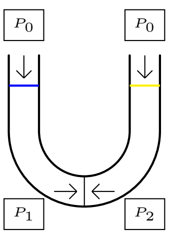
## Exercise 1:

Data:

1. 25 cm of water.
2. 25 cm of oil.
3. Density of oil 0.8.
4. Density of water 1.




### A appart

Final height when barrier is removed

$$P_1 = P_0 + \rho_1 \cdot g \cdot h_1$$
$$P_2 = P_0 + \rho_2 \cdot g \cdot h_2$$

Being $P_1$ the pressure done by the water and $P_2$ the pressure done by the oil
We know that to be in equilibrium $P_1 = P_2$, so we have:

$$\begin{cases} P_1 = P_2 \\ h_1 + h_2 = 50 \end{cases} \Rightarrow \begin{cases} P_0 + \rho_1 \cdot g \cdot h_1 = P_0 + \rho_2 \cdot g \cdot h_2 \\ h_1 + h_2 = 50 \end{cases} \Rightarrow \begin{cases} \rho_1 \cdot h_1 = \rho_2 \cdot h_2 \\ h_1 + h_2 = 50 \end{cases}$$
$$\Rightarrow \begin{cases} h_1 = 0.8 \cdot h_2 \\ h_1 + h_2 = 50 \end{cases} \Rightarrow \begin{cases} h_1 = 22.2cm \\ h_2 = 27.8cm \end{cases}$$

So the height of the water will be 22.2cm and the height of the oil 27.8cm

### B appart

If the had equal densities the height will be the same as the properties and conditions of the liquids will be the same (they will do the same pressure)

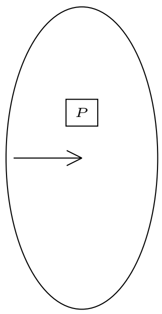
### C appart

If the oil density would be much less, the water height would be much less and the oil one much bigger (the oil would do less pressure)

# Exercise 2:

Data:

1. Force on the tympanic membrane increased by about 1.5 N above the force from atmospheric pressure, the membrane can be damaged.
2. Eardrum 82mm of diameter (0.0041m of radius).
3. Density of oil 0.8.
4. Density of seawater $1.03 \cdot 10^3 kg/m^3$.




At what depth scuba diving can the eardrum be damaged

$$P = P_0 + \rho \cdot g \cdot h$$

We know that $P_0 = \frac{F}{A}$, and knowing that if we increase the force by 1.5N we could damage the eardrum, so $P = \frac{F+1.5N}{A}$, this transforms to $P = \frac{F}{A} + \frac{1.5N}{A} \Rightarrow P = P_0 + \frac{1.5N}{A}$, so:

$$P_0 + \frac{1.5}{A} = P_0 + \rho \cdot g \cdot h \Rightarrow \frac{1.5}{A} = \rho \cdot g \cdot h$$

$$\Rightarrow h = \frac{1.5}{A \cdot \rho \cdot g}$$

Being the area $\pi \cdot r^2$:

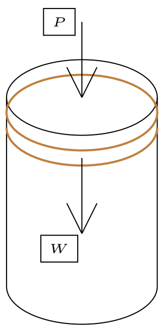
$$h = \frac{1.5}{\pi \cdot r^2 \cdot \rho \cdot g} \Rightarrow h = \frac{1.5}{\pi \cdot 0.0041^2 \cdot 1.03 \cdot 10^3 \cdot 9.8} = 2.8m$$

So the depth will be 2.8m

# Exercise 3:

Data:

1. Weight 45N
2. Diameter 30cm (0.3m)
3. Density of oil $0.850 g/cm^3$ ($850 kg/mm^3$).
4. 75cm deep (0.75m).




## A appart

What is the gauge pressure at the top of the oil column? In this case as a disk is at the top of the cylinder, the pressure will be done by the weight of the disk, so:

$$P = \frac{F}{A} \Rightarrow P = \frac{45}{A} = \frac{45}{0.015^2 \cdot \pi} = 636.62 Pa$$

So the gauge pressure at the top will be 636.62Pa

## B appart

Now we add a weight of 83N at the top, compute change of pressure at the bottom (I) and at the halfway (II)

### I

The total weight will be now $45 + 83 = 128N$, so the pressure at the top will be $P = \frac{F}{A} = 1810.8 Pa$, so the pressure at the bottom will be computed as:

$$P_{bot} = P_{top} + p \cdot g \cdot h \Rightarrow P_{bot} = 1810.8 + 850 \cdot 9.8 \cdot 0.75 = 8058.3 Pa$$

So the pressure at the bottom is 8058.3Pa

### II

The pressure at the halfway will be computed as:

$$P_{bot} = P_{top} + p \cdot g \cdot h \Rightarrow P_{bot} = 1810.8 + 850 \cdot 9.8 \cdot 0.375 = 4934.55 Pa$$

So the pressure at the halfway is 4934.55Pa

# Exercise 4:

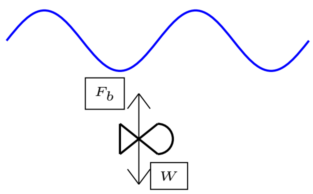
## A appart

It tells me that they have the ability to modify their density to make it bigger (to go deeper) or smaller (to go higher). They probably do this by changing their volume

## B appart

Data:

1. 2.75kg fish
2. Increases its volume by 10%




Find the net force the water exerts on it So the water will exert a buoyant force, this force is computed as:

$$F_b = m_L \cdot g \Rightarrow F_b = \rho_L \cdot V \cdot g$$

We know the fish has increased his volume by 10%, so the new volume will be $V \cdot 1.1$

Now we need to get the original volume of the fish, for that we have to assume that before inflating the sac it was in equilibrium, so $F_b = Weight$, so:

$$\rho_L \cdot V \cdot g = m_{fish} \cdot g \Rightarrow V = \frac{m_{fish}}{\rho L} = V = \frac{2.75}{1000} = 0.00275m^3$$

With that, now we can compute the new buoyant force, so

$$F_{bnew} = \rho_L \cdot V \cdot 1.1 \cdot g \Rightarrow F_{bnew} = 1000 \cdot 0.00275 \cdot 1.1 \cdot 9.8 = 29.645N$$

So the force the water will exert is 29.645N

## C appart

What is the net external force on it? Does the fish go up or down when it inflates itself?
Now we know the new buoyant force and the weight, so:

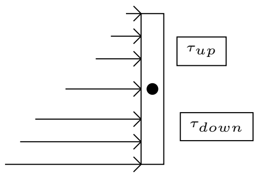
$$F_{net} = F_{bnew} - Weight \Rightarrow F_{net} = 29.645 - 2.75 \cdot 9.8 = 5.145N$$

The next external force is 5.145N, so the fish will go up (as he lowered his density by increasing his volume)

# Exercise 5:

Data:

1. Gate of 2m high
2. Gate of 4m wide




Calculate the torque about the hinge arising from the force due to the water

We know the torque is $\tau = \overrightarrow{r} \times \overrightarrow{F}$, we also know that the force exerted will be the pressure on the gate times the area, so $F = P \cdot A$, and that the area is computed as $A = width \cdot height$, and that the pressure is computed as $P = \rho \cdot g \cdot h$

The problem here is that the pressure will increase as we go deeper, so we will have to define an integral to compute the torque. For that we will divide the problem in two parts, first we will compute the torque in the up part and after that in the bottom part, finally we will add them to get the total torque

## Top part

To define the integral of the torque we will start by this:

$$\tau = -1 \cdot r \cdot F$$

We put the -1 as the result of the cross product will be towards the inside. Then we need to define the differentials:

$$d\tau = -1 \cdot r \cdot dF$$

To define dF we need to go to the $F = P \cdot A$ formula, so:

$$dF = P \cdot dA$$

To define dA we need to go to the $A = P \cdot A$ formula, so:

$$dA = Width \cdot dy$$

We do it in this way because the pressure will vary by the height. So putting it all together will it be:

$$d\tau = -1 \cdot r \cdot \rho \cdot g \cdot y \cdot Width \cdot dy$$

But what is r here? As the edge of rotation is at depth 1 and the integral will go from 0 to 1 (top part), r will be (1-y), so (we also substitute the width as we know it):

$$d\tau = -1 \cdot (1 - y) \cdot \rho \cdot g \cdot y \cdot 4 \cdot dy$$

And integrating it will result in:

$$\tau = \int_0^1 -1 \cdot (1 - y) \cdot \rho \cdot g \cdot y \cdot 4 \, dy$$

This will give a result of $-6.53 \cdot 10^3$ N/m

## Bottom part

The development for the bottom part will be the same, but in this case the things that will change will be r and the -1 by a 1. The -1 will be a 1 because of the cross product result (outwards), and r will be now 1+y, as the integral will be from 1 to 2 and the axis of rotation is at depth 1, so:

$$\tau = \int_1^2 (y + 1) \cdot \rho \cdot g \cdot y \cdot 4 \, dy$$

This will give a result of $1.5 \cdot 10^5$ N/m

## Final part

Now we only need to compute the net torque by adding the two computed ones, so the result will be $1.43 \cdot 10^5 \mathrm{N/m}$