ACUC

# Open Water Diver

Part 3

Physics aspects

# 3 Physical aspects

In this section we will see some physical aspects that we need to know to better understand the changes that occur in the underwater environment and, above all, the great difference with respect to the ambient pressure, that in this and other chapters of this manual, we will see that it affects us very directly.

Throughout all the explanations we will try to use a language as simple as possible, as well as explain the phenomena in a brief and simple manner, although sometimes we may err on the side of imprecision, since the objective is not for the student to learn physics, but to understand the physical phenomena and to what extent it can affect us.

## 3.1 Pressure concept

Pressure is defined as a force exerted on a surface. For example, if we stand in a newly snow-covered landscape, we exert a weight on the snow (a force) that we apply on a surface (the surface covered by our shoes). That force / surface reference is what is called pressure. Due to that pressure, we sink into the snow, but if we do the same thing with snow rackets, we will see that we do not sink as much, but the weight is the same (even more because of the rackets) but we sink less because the pressure is lower, it is the same force (our weight) but applied to a larger surface (the rackets) so the pressure is lower.

The air weighs, although we do not realize it, in fact Torricelli managed to carry out the first measurement in 1643, by means of a column of mercury, establishing the value of the weight of the air as equivalent to a column of mercury of 1 cm2 of surface and 760 mm of height. That means that the atmospheric pressure equals 760 mm / Hg, which is about 1 kg. The atmosphere exerts a weight on the earth surface of just about one kilo per square centimetre. Since it is a weight relating to a surface, we call it pressure. In everything related to diving, we call that measure “atmosphere” (abbreviation atm) or “bar” (without plural). That is, for diving purposes, a pressure of 5 kg per square centimetre is the same as 5 atmospheres or 5 bar (5 kg / $cm^2$ = 5 atm = 5 bar).

The atmospheric pressure at sea level is 1 atm; sea level is the lowest point on earth in our normal habitat, so if we climb to higher points, i.e. at a mountain, the column of air above us is shorter, so it weighs less, so the pressure decreases. A barometer would give us the pressure of the place in millibar (1000 millibar = 1 bar). At about 5000 m of altitude the atmospheric pressure would be 0.5 bar, it is half that at sea level.

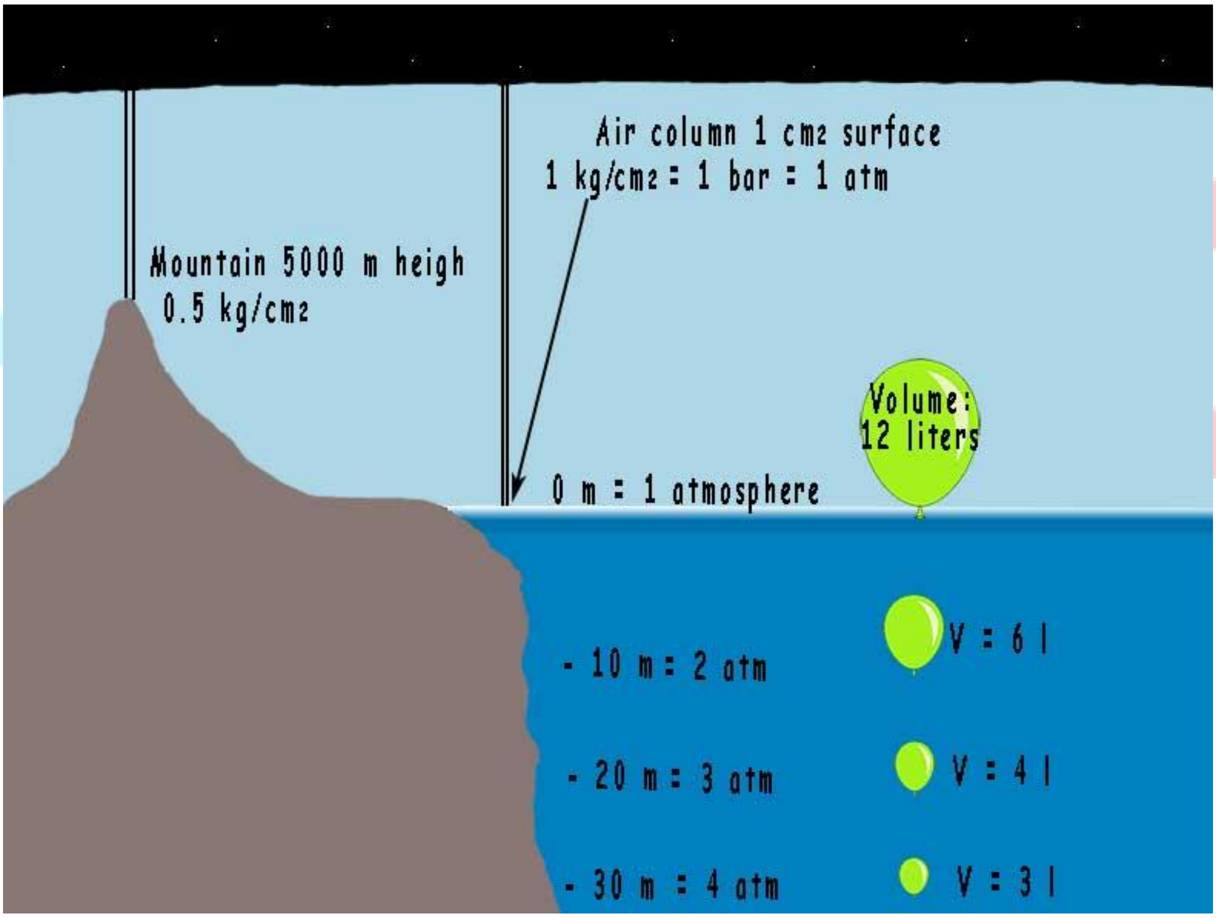
Water also weighs, and much more than air. A 1 $cm^2$ column of water of 10 meter of height is equivalent to a litre of water and a litre of water weighs 1 kg (rounded up). This means that the water exerts a pressure of 1 bar (or 1 atm) for every 10 metres of depth. This is called relative pressure.

The concept that we have yet to know is that of absolute pressure, which it is the sum of atmospheric and relative pressures. We are going to assume that we are at sea level, because for diving at other heights specific knowledge is needed, so the absolute pressure will be the pressure relative to the water plus 1 (the atmospheric one) and to know the pressure relative to the water, you only have to divide the depth (in metres) by 10, as every 10 metres it is 1 bar. That is, at 17 metres depth, for example, we will bear an absolute pressure of 2.7 bar ((17/10) +1). All the examples and data given refer to the pressure at sea level. Water will always have the same relative pressure, regardless of altitude, but as the atmospheric pressure is lower, the pressure ratio changes dramatically. For that reason, the calculation of altitude dives is offered in another more advanced course.

There is a very important and very interesting issue for divers, which we must keep in mind and it is the pressure variation ratio. In this small list below, we indicate the different pressures at different depths and what it increases from the previous depth, in percentage and in fraction, so that we can see what we are talking about:

| Depth | Relative pressure | Atmospheric press. | Absolute press. | % increase |
|---|---|---|---|---|
| 0 | 0 | 1 | 1 | -- |
| 10 | 1 | 1 | 2 | 100% (double) |
| 20 | 2 | 1 | 3 | 50% (1/2) |
| 30 | 3 | 1 | 4 | 33% (1/3) |
| 40 | 4 | 1 | 5 | 25% (1/4) |
| 50 | 5 | 1 | 6 | 20% (1/5) |
| 60 | 6 | 1 | 7 | 17% (1/6) |
| 70 | 7 | 1 | 8 | 14% (1/7) |

We can notice that if we go from 0 to 10 metres down, the pressure is doubled, because from 1 we go to 2 atmospheres, so the pressure ratio is of 2:1; however, going from 10 to 20 metres down no longer doubles, but increases 50%, if we go from 20 to 30 metres down, the pressure increases 33% even if in all cases we have been going 10 m down. As we can see, the pressure increase ratio decreases as we move away from the surface.



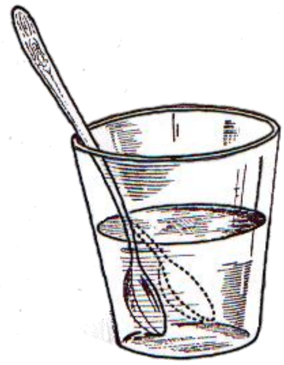

In the first 10 metres the pressure has doubled, but to double this pressure at 10 metres, we would have to dive to 30 metres and to double the pressure from 30 metres we would have to dive to 70 metres. That is, to achieve at 30 m the same pressure variation that we have achieved by diving from 0 to 10 m, would force us to go down 40 m more, from 30 to 70 m deep. At 3 metres deep we are at 1.3 bars, that is, a pressure 30% greater than at the surface.

What we have to learn from this, is that the rate of pressure variation gets larger the closer we are to the surface. For that reason, the idea that diving at a shallow depth does not require training is totally wrong. We will learn some consequences derived from the variation of pressure being, as we have seen, this variation more drastic as we approach the surface.

## 3.2 Light

Our sight is adapted to the air environment. We are able to see with a wide range of light intensity and we are able to differentiate colours when the intensity of the light allows it (in semidarkness we do not distinguish colours). Our eyes project the image on the retina thanks to the refractions that occur in the eyeball and, if we do not have any visual impairment, we see our surroundings sharp, well focused. Under the water some changes do happen. If we open our eyes underwater (without a mask), we will see that our vision is very blurred.

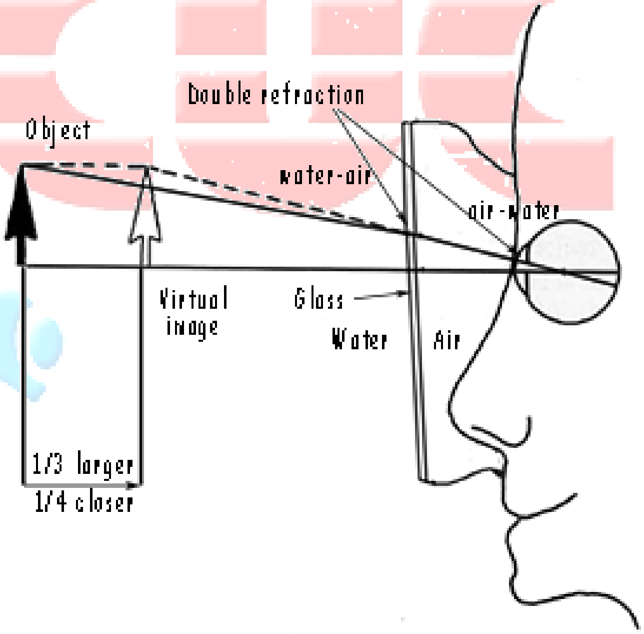
### 3.2.1 Refraction



It is the optical phenomenon that we can observe when we put a rod or spoon in a glass of water, which seems to bend at an angle. What happens is that the water / air refractive index is approximately 1.33 and that is why the angle changes. The same happens in our eyes.

The air / water refraction in our eye allows the image to be clearly projected on the retina, but when the eye is in contact with water, such refraction does not happen so the sharp image is not formed in the retina but it forms behind it, so we become very farsighted, but that is solved with the diving mask, since it provides an air space to our eyes which allows us to recover the air / water refraction and our sight is clear again.

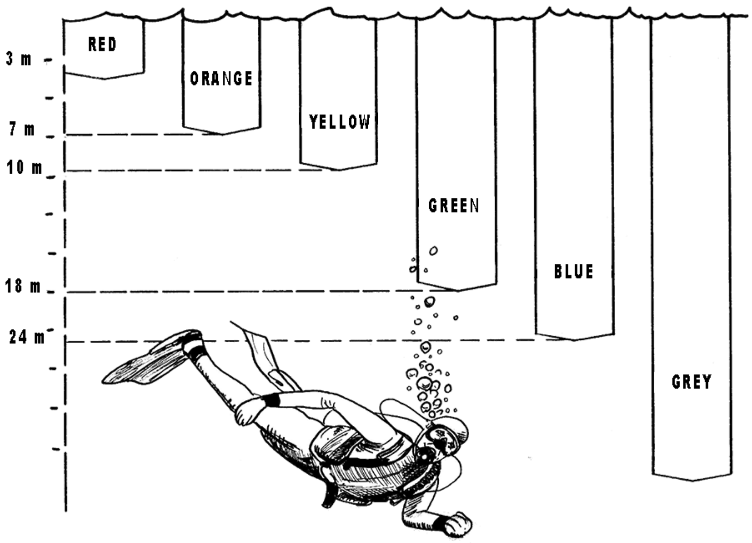
But now another one phenomenon happens which is the double refraction. When putting on the mask, under water, water / air refraction occurs when the light goes through inside the mask and another air / water refraction as the light from inside the mask goes through inside our eye. This double refraction causes the apparent size and distance of the objects to be modified. We see objects about a third larger than they really are and we also see them about a quarter closer than they really are. It is very typical to see a new diver reaching out to grab the anchor line and failing, since the line is somewhat further away than the diver perceives it.




### 3.2.2 The absorption

Of light is responsible for the loss of colour. Light is composed of colours of different wavelengths (which we will call different intensity), whose decomposition can be seen in the rainbow. The full set of colours form the white light. As the water is so dense with respect of the air, an absorption of the light takes place but we call it selective, as the light is absorbed by colours as we go down. Since red is the colour with less intensity, it is the first one lost. At 5 metres deep (15 feet) we are no longer able to see the red, at 12 metres deep (36 feet) we do not see the yellow and so on, our environment and the objects acquire a blue-gray tone and we do not distinguish any colour at about 30 metres (90 feet), for that reason, if we switch on a dive light, an explosion of colour takes place, as we bring the light to the objects when illuminating them. Now the light only covers the distance from our focus to the object and the reflection from the object to our eyes, so we can see even the red colours.

The phenomenon of absorption is intensified with the turbidity of water, as the particles are opaque, so that in turbid waters, at shallow depth there may be total darkness and usually, under the sea, below about 200 m depth (600 feet) the darkness is virtually total.




### 3.2.3 Reflection

Is another phenomenon that limits light intensity. When the light hits the surface of the water, part of it is reflected to the atmosphere and part penetrates the water. The quantity of reflected light depends on the light angle of incidence, being minimal when the incidence is vertical, that is why the lighting is very poor at dawn and twilight and the maximum illumination is in the central hours of the day.

The result of all these phenomena is that there is less light underwater and so, less colour. If we want to do photo or video, we will need flash or spotlights for recording the fullness of colours found on the seabed.

## 3.3 Sound

Sound travels in the air at about a speed of 340 metres per second. Our nervous system is able to detect the differences of time and intensity of the arrival of sound to each of our ears and from there we are able to locate the source of sound, that is, we can discern if the sound comes from the left, from the right, from behind or from the front although we cannot see the sound source.

In salt water, the sound travels at about 1500 metres per second, something more than 4 times faster than in the air, that means we are able to hear sounds at such distances that we would not hear in the air, but it also means that we are not able to locate the source of sound. That higher speed prevents us from knowing if the sound comes from our right or from our left, for example. A diver can try to call our attention by hitting his tank, surely we will hear the sound, but we will not know where it comes from unless we are seeing him.

Nevertheless, we are not able to speak, since modulating the voice requires a gaseous volume and understanding what is spoken too, so we need means to communicate with our buddy. To solve this, there is a set of hand signals of international use, taught all over the world by all organizations, which solve basic safety communication. The files signals.jpg show you the signals used. However, for safety, signals must be confirmed with the buddy before starting the dive, as some secondary signals may have some variation from one place to another.

The most important signals, such as the OK to the buddy, problems, lack of air, etc., are the same, without any difference, in any country, but the briefing with the buddy is necessary to make sure that we are also going to understand other signals. Although you will train the signals in your practices in water, here we show them to you in two images that you can download.

The signals involve both question and confirmation; that is, if we make the OK signal to the buddy, we are indicating that we are fine and asking him or her too. **Always** answer any signal, as that indicates that we have seen the signal and with our reply we also inform that we have understood it. If we use, for example, the signal "Something is wrong" we must use another one to say what goes wrong, as it may be to indicate the regulator, the ear, etc. The answer to that signal will be with the signal "Let's go up".

Another example is the "I do not have air" signal that is made when there is not enough air available to go up. The answer is to offer our reserve regulator and make the signal to ascend. Serve as an example, but what we must learn is that all signals must be answered with common sense. This is only an example, but what we must learn is that all signals must be answered.

Due also to the effects of the mask and refraction, our sight under water is "narrower", our peripheral sight is very limited, so we have to do the signs slowly and make sure we do it in front of the buddy's sight, maintaining the sign for a short time until we make sure he sees them. Under the water we cannot "look sideways". If we want to look at something on one side, we have to turn our head.

Please, download the two images in which we show you the most common signals and after looking at them carefully with their meaning, download the self-evaluation document, to verify that you answer all the questions correctly. You can repeat the exercise as many times you need until you answer correctly.