Physics Study Notes

Water and Heat - Heat loss is 20 times faster in water (than air) due mostly to conduction because water conducts heat more efficiently as the molecules are closer together.

**Conduction** is the transmission of heat via direct contact

**Convection** is the transmission of heat via fluid dynamics. As a fluid is heated it rises and is replaced by cooler fluid drawing heat away

**Radiation** is heat transmission via electromagnetic waves

Water and Light - Speed of light depends on the density of the medium it is traveling through. When light goes from one medium to another (different densities) it changes speed, which causes light rays to alter direction or bend (refraction).

**Turbidity** is a concentration of suspended particles (plankton or silt)

Refraction magnifies objects underwater making them appear 33% larger and 25% closer. Visual reversal makes objects appear small & further away (caused by turbidity)

Water and Sound - Sound travels 4 times faster in water than air. Sound moves as pressure waves and so travels faster in more dense mediums. In water direction of sound is difficult to determine but seems to come from above.

Buoyancy - An object immersed in a fluid is buoyed up by a force equal to the weight of the fluid displaced by the object

Fresh water 1 litre = 1kg,

Sea Water 1 litre = 1.03kg

To calculate an objects’ buoyancy you need to know; its weight, the volume of water displaced, the constant to use (fresh or salt water)

Buoyancy is calculated as;

Downward force (weight of object) minus Upward force (weight of water displaced)

**Example** - Weight 175 kg (downward force)

Displacement 74 litres of salt water (upward force)

\[
175 \text{ kg} - (74 \text{ l} \times 1.03 \text{ kg/l})
\]

\[
175 \text{ kg} - 76.22 \text{ kg} = 98.78 \text{ kg}
\]

Overall force displacement is 98.78 kg downwards. Therefore the object is negatively buoyant and will sink.
GoPro Utila Dive Theory - Study Notes

**Pressure and Water** - water has weight and therefore exerts pressure

**Boyle’s Law** - Pressure is directly proportional to the density
Volume is indirectly proportional to the pressure

<table>
<thead>
<tr>
<th>Depth - SW</th>
<th>Pressure ATMG</th>
<th>Pressure ATA</th>
<th>Volume</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 meter</td>
<td>0.1</td>
<td>1.1</td>
<td>.9</td>
<td>1.1</td>
</tr>
<tr>
<td>10 meter</td>
<td>2</td>
<td>2.0</td>
<td>.5</td>
<td>2</td>
</tr>
<tr>
<td>15 meter</td>
<td>1.5</td>
<td>2.5</td>
<td>.4</td>
<td>2.4</td>
</tr>
<tr>
<td>20 meter</td>
<td>2.0</td>
<td>3.0</td>
<td>.3</td>
<td>3</td>
</tr>
</tbody>
</table>

**Depth and Density** - As a gas filled object descends the ambient pressure increases and the volume will decrease (assuming the object is flexible); the loss of volume for the gas to occupy results in greater density of the gas. This has several effects on a diver; air consumption rate increases, a greater quantity of gas is absorbed and physiological effects of the gas increase (narcosis).

**Pressure, volume & temperature** - rules of thumb when dealing with gases in a fixed volume container (cylinder):
· Pressure and temperature have a direct relationship. As pressure increases, so will temperature. As pressure decreases, so will temperature.
· Temperature increase will result in pressure increase; a temperature decrease will result in a pressure decrease.
· Tank pressure change is 0.6 BAR per degree Celsius change (5 PSI per degree Fahrenheit)

**Partial Pressure** - each gas in a mixture exerts its own pressure based on the percentage of that gas in the mixture. This affects a diver as our physiology reacts to increased or decreased partial pressure; an example of this is narcosis. Partial pressure at depth is calculated by multiplying the % of the gas by the absolute pressure at that depth. An example is oxygen partial pressure at 30 meters/100 feet is 0.21ppO2 X 4ata = 0.84ppO2

**Surface equivalency** - although the pressure inside a cylinder is not affected by depth
(and therefore the partial pressure of each gas in the cylinder remains static) we inhale a higher partial pressure of gases directly proportional to the absolute pressure. This is termed ‘surface equivalency’ and is used to predict the physiological affect of gases at depth on a diver. An example is breathing from a cylinder filled with EANx 36 at 20 meters/66 feet would be the equivalent of breathing 108% O2 at the surface (0.36ppO2 X 3ata = 1.08ppO2).

**Gas absorption** - If the ambient pressure surrounding a liquid is increased it will begin to absorb that gas until it reaches a state of equilibrium with the surrounding pressure; the liquid has then reached saturation. If the ambient pressure is decreased the liquid will be in a state of ‘supersaturation’ and will begin to release the gas until the state of equilibrium is reached. Excessive speed of gas release in a diver explains bubble development & DCS.

**Physiology Study Notes**

Main purpose of the **respiratory** and **circulatory** systems is to supply oxygen and other nutrients to the body tissues and remove CO2 and other waste products.

**Arteries** carry blood away from the heart
**Veins** carry blood to the heart
**Capillaries** are microscopic vessels where blood interacts with tissues for example the pulmonary capillaries in the lungs
**Hemoglobin** is a protein in the red blood cells that bonds with oxygen and carries delivers the bulk of the body/tissue oxygen needs

‘**Dead air space**’ is an oxygen poor area when air is left over in the respiratory system after exhalation & therefore the first air into the lungs upon subsequent inhalation. Divers reduce the effect of having a ‘dead air space’ by breathing slowly and deeply

**Apnea** means ‘breath holding’
**Bradycardia** is a slowing of the heart - usually associated with cold water on the face (this relationship is called the ‘mammalian diving reflex’)
**Hypoxia** means an insufficient oxygen supply to the body tissues
**Hypercapnia** is excessive CO2
**Hypocapnia** is insufficient CO2

The breathing reflex is mostly attributed to increased levels of CO2 in the lungs. Hyperventilation may increase breath hold (Apnea) time by causing Hypocapnia, delaying the bodies’ ability to detect the need to breathe
**Shallow water black out** is caused by excessive hyperventilation before free diving. At
depth the brain is supplied by oxygen due to the increased partial pressure at depth. Upon ascent the pp is reduced due to the dropping ambient pressure to the point where there is insufficient oxygen supply to the brain causing hypoxia and either unconsciousness or loss of motor skills.

**Carotid sinus reflex** is experienced when there is excessive pressure upon the carotid artery (tight hood or neck seal) causing the brain to interpret an increase of blood pressure in the brain, the heart is then directed to slow delivery of blood to the brain resulting in hypoxia and possibly unconsciousness.

**Carbon monoxide** (CO) bonds more than 200 times more readily to hemoglobin than oxygen. This can mean that exposure to CO can leave the blood unable to transport an adequate supply of oxygen, causing hypoxia and in extreme cases unconsciousness. Symptoms include; cherry red lips and nail beds, headache, and confusion. A pp of 2.5% can be lethal. It may take the body over 12 hours to eliminate CO.

O2 Toxicity is caused by increased pp of Oxygen (in excess of 1.4 pp). It is a concern when breathing Oxygen enriched gases at depth. There are 2 types.

CNS O2 Toxicity is directly related to exceeding a 1.4 pp of O2. Pulmonary Toxicity is caused by breathing high pp's of O2 over an extended period. This is usually only a concern for Tec divers decompressing on elevated O2 percentages (100%?)

**DCS, or Decompression Sickness** (a.k.a. ‘The Bends”) caused by bubbles in the divers body. There are 2 types; Type 1 - pain only in the limbs and joints, Type 2 - affects the brain and spinal cord (life threatening).

Heat Exhaustion - body’s resources are taxed trying to cool down
Heat Stroke - body’s thermostat has failed. The body is no longer trying to cool itself; this is life threatening and needs immediate EMS attention

**Barotrauma** is a pressure injury to a body space that can be caused on either ascent or descent.

**Middle ear squeeze** is a failure or inability to equalize due to congestion. If the pressure cannot be equalized the body will allow the hydrostatic pressure to force blood and fluid into the middle ear until equilibrium is restored. Ears will then feel ‘full’, hearing will be ‘muffled’.

**Eardrum rupture** is due to a failure to equalize, the pressure increases faster than fluid can fill the middle ear (see ‘middle ear squeeze’). The eardrum tears, a sensation of sharp pain is followed by relief and possibly vertigo as cold water touches the vestibular canals.
**Reverse squeeze** is caused by congestion or another blockage in a body air space during ascent. Expanding air causes barotrauma as it tries to escape body air space.

**Round window rupture** is caused by a forceful valsava maneuver.

**Lung over expansion** injuries include; Air embolism, Pneumothorax, Mediastinal Emphysema, and Subcutaneous Emphysema.

**Air embolism** (also called arterial gas embolism) simply means a foreign substance in the arteries. In this case usually a tear in the lung lining allows air to directly enter the blood stream which makes bubbles being moved directly to the brain a high possibility.

**Pneumothorax** is a collapsed lung.

**Mediastinal Emphysema** is bubbles collecting inside the rib cage in the center of the chest. This may put pressure over the heart.

**Subcutaneous Emphysema** is bubbles accumulating in the soft tissues at the base of the neck.

**Deco Theory and the RDP**

Use the instructions for use booklets & DM exam to practice your use of the RDP table, wheel and eRDP. Be sure to read over the special rules printed on the bottom of the RDP’s.

**Compartments** - are theoretical, have certain characteristics meant to represent tissues in the human body - but have no direct relation to actual parts of the human body. US Navy tables were originally developed using 5 compartments, later revised to 6, the DSAT RDP has 14 compartments. Compartment characteristics include:

- **Halftimes** are the rate at which the compartment absorbs and releases gas.
- **M-values** are the maximum gas pressures safely allowed in a compartment upon surfacing.

Fast compartments have higher M - values; slow Compartments have lower M - values. The controlling compartment for a dive is the one that reaches its M - value first.
The controlling compartment for surface intervals on the US Navy tables is 120 minutes, on the DSAT RDP it is 60 minutes. This means the RDP’s will allow shorter surface intervals and longer repetitive dives than the US Navy tables. This also explains why a dive is only repetitive before 360 minutes has expired; 6 (½ times) X 60 (minutes) = 360

Halftime is described as the time it takes a compartment to go from starting pressure halfway to saturation. For simplicity we determine a compartment to be saturated after it has experienced 6 halftimes. Original Haldanean halftimes ranged from 5 to 75mins; modern halftimes range from 3 to 600mins, the RDP has compartments with ½ times that range from 5 to 480 minutes.

Letters are interchangeable on DSAT RDP’s but not interchangeable between tables from different manufacturers as the letters will represent different theoretical values of nitrogen.

**Equipment**

**Tanks and Valves**

Scuba cylinders will have the following markings:

- Government agency responsible for approval – DOT, TC
- Alloy designation – 3AL Aluminum, 3AA Steel
- Fill pressure
- Serial number
- Hydrostatic test date and identifying mark of the testing agency

Steel is stronger than Aluminum so steel tanks have thinner walls and higher internal volume for a given size therefore hold more air at given pressure. Aluminum is less subject to structural weakening due to corrosion. Corrosion in steel tanks is called rust whilst in Aluminum is called Aluminum Oxide.

**Visual Inspections** should be done every year or more often depending on the frequency of the cylinders use.

Hydrostatic Testing – is done every 5 years to ensure the structural integrity of the cylinder.

- Tank is filled with and immersed in water and the volume measured
- The tank is then pressurized beyond normal working pressure (5/3rds its max working pressure – 5000 PSI or 345 BAR).
- This pressurization causes displacement of the water on the outside which is then measured
- The pressure is then reduced and the tank volume is measured again
GoPro Utila Dive Theory - Study Notes

- If the difference between the volumes and displacement of water is within limits the tank passes

**K Valve** - is a simple turn on/off screw design for opening the cylinder. The 1st stage of the regulator uses a yoke design; the most common design in recreational diving.

**J Valve** - is an older version. It has an additional spring mechanism/lever that holds in reserve 30 BAR/500 PSI to alert the diver their air supply is getting low. This was common when divers did not have SPGs. The tank can only be filled with the lever in the ‘down’ or ‘reserve open’ position.

**DIN Valve** - has a threaded port that allows the 1st stage of the regulator to be screwed directly into the tank valve. This is a stronger connection allowing higher working pressures, a better o-ring seal and reduces the chance of impact dislodging the 1st stage in a wreck/cave. It is more common in the Tec diving market.

Burst Disc - tank valves also include a safety feature called a ‘burst disc’ - which is a small copper plate that will safely rupture and allow the release of pressure if the tank is over pressurized.

**Regulators**

The 1st stage regulator reduces tank pressure to ‘intermediate’ pressure which is normally 5-10 BAR or 70-140 PSI above ambient pressure.

The 2nd stage regulators, both primary and secondary, are demand valves. Inhalation effort reduces pressure on the inside of a diaphragm which flexes inward opening the valve and allows air to flow from the tank into the regulator. When inhalation effort (demand) stops, the diaphragm returns to its resting position and air flow stops.

Downstream Valves are found in regulators. They open in the direction of air flow and are referred to as ‘fail safe’. If there is a malfunction, the valve sticks open, causing a ‘free flow’ of air. A pilot valve is a ‘slave’ valve found in the 2nd stage. A pilot valve assists the main 2nd stage valve to open, thus reducing inhalation effort and breathing resistance.

Balanced regulators deliver air to the diver at the same inhalation effort even as tank pressure drops; they are found in the 1st stage. An unbalanced regulator ease of breathing depends on tank pressure, as the pressure drops, inhalation effort increases.

Open Circuit SCUBA refers to the fact that exhaled gases are released into the surrounding water. It is the most common type of SCUBA found in recreational diving. Closed Circuit SCUBA refers to the fact that exhaled gases are returned to the breathing unit to be recycled. A ‘ rebreather’ is another name for this system.