SMS-204: Integrative Marine Sciences.

Mid-term examination (physics part)

Answers are provided in *italics*.

Please answer all questions (total time 50min): Please provide a <u>short</u> answer to the 7 following questions (6pts each). Please provide your derivations so I can provide you with partial credit in case the answer is not correct.

1. A submarine weighs 30,000Kg in air and has a volume of $20m^3$ floats in a harbor. The submarine sank to the bottom of the harbor. What force do we need to apply to raise it from the bottom (assume the volume of the material the submarine is made off is negligible and that the density of water is $1000kg/m^3$)?

Two possible answers: 1. The submarine has a volume of 20m^3 and thus the mass of the displaced water is 20,000kg (assuming it is not filled with water when it sank).
Thus, the weight in water is 30,000-20,000=10,000kg. The force needed to lift it is the mass times the gravitational acceleration, F=Mg=98,100N.
2. If the submarine got flooded with water, it does not displace any water (remember that the volume its solid part is negligible) and thus its weight in water is the same as in air. In this case F=Mg=249,300N. Another way to think about is that the buoyancy cancels exactly the added weight due to water within the sub.

2. A fishing vessel cruises at a constant speed while trawling.
   a. How many cubic meters of water enter the fishing net ($100m^2$ area) each minute as it cruises through the water at 10 m s^{-1}?
   b. How many fish can be caught if the concentration of fish is 1 per m^3?
   c. If each fish weigh 1kg, how many kg fish are caught per day?

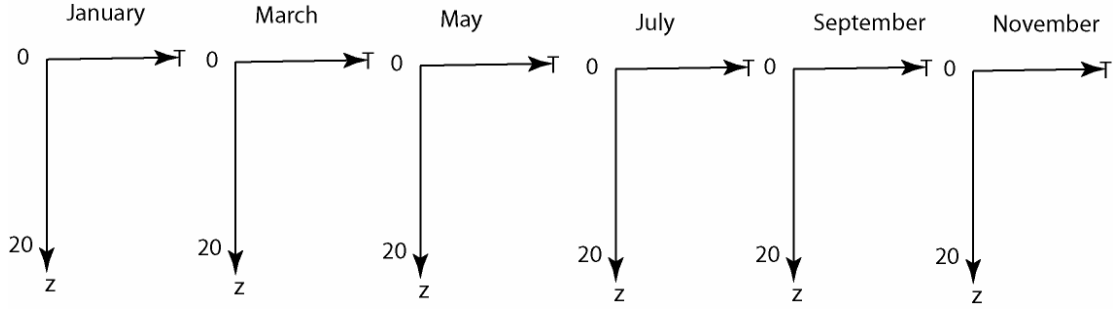
a. $100m^2 \cdot 10m\ s^{-1} \cdot 60s\ min^{-1} = 60000m^3\ min^{-1}$
b. $1\ fish\ m^{-3} \cdot 60000m^3\ min^{-1} = 60000fish\ min^{-1}$
c. $1Kg\ fish^{-1} \cdot 60000fish\ min^{-1} \cdot 1440min\ day^{-1} = 86,400,000Kg\ day^{-1}$

4 (for 3 see next page). What is the Reynolds number a 50cm long tuna swimming at 2m/s in water (kinematic viscosity = $10^{-6}m^2/s$)? What is it for a bacteria (1micron=10^{-6}m) swimming four body lengths a second?

Tuna: $Re=LU/\nu=0.5m \cdot 2m\ s^{-1} / 10^{-6}m^2/s = 10^6$ [unit less]

Bacterium: $Re=LU/\nu=10^{-6}m \cdot 4 \cdot 10^{-6}\ m\ s^{-1} / 10^{-6}m^2/s = 4 \cdot 10^{-6}$ [unit less]

3. Plot possible temperature profiles for a lake in Maine (depth 20m) as function of time (one plot every two months, starting in January, a total of 6 plots). Assume the lake is covered with ice from December to March. Provide the temperature values at the surface and at depth (maximum temperature of the lake is 20degree C and the minimal is 0degree C below the ice. Remember that water density is not monotonic with temperature.



Several details I expected you to remember:

1. *Coldest at surface March warmest in September.*
2. *The temperature of maximum density is 4C. Once the whole water column has become 4C it restratifies.*
3. *Deep waters are denser than surface waters.*

5. You are asked by the US Geological Survey to measure the amount of sediments that is transported downstream by the Penobscot River near Bangor (sediment are measured in Kg/m^3 dry weight). How would you go about determining the transport of sediment downstream? What properties do you need to measure? Provide an example of the units for sediment transport?

Measure water velocity, sediment concentration, and cross sectional area Measure both velocity and concentration at several places within the cross section of the river to get a good estimate for the mean velocity and mean concentration.
*The sediment transport is equals to [with dimensions in square brackets: mean velocity [L/T] * sediment concentration [M/L^3]* cross sectional area [L^2], in dimensions of mass per time [M/T], such as Kg sediment per second.*

6. Why is a deep snorkel not a practical tool for sub-surface diving while SCUBA is?

At depths exceeding a few feet the surrounding pressure is too great for our body to be able to inflate the lungs. SCUBA provides pressurized air allowing our body to inflate the lungs against the ambient pressure.

7. Name the three mechanisms for heat transfer. Give one example for each that may be relevant to a marine organism?

Conduction, convection and radiation. Conduction is the heat loss or gain by transfer of heat from the water to all marine organisms. Convection involves the rising and sinking of water as heat changes the water density. Relevant to mixing of phytoplankton in the mixed layer. Radiation is the conversion of photons to heat. These occur for all absorbing

organisms, such as algae in the surface ocean. Only a small fraction of the photons are used for photosynthesis, while most are converted to heat.

True/False questions (2pts each):

a. In water, pressure decreases with depth. *F*
b. A submerged body experience an upward force equal to its volume times the density of water. *F*
c. Work and energy have the same units. *T*
d. A blue object absorbs preferentially in the blue. *F*
e. A solid object completely immersed in salty water experience more upward buoyant force than when it is immersed in fresh water of the same temperature. *T*
f. Surface tension can cause an object that would otherwise sink to float on water. *T*
g. The no-slip condition implies that swimming organisms experience drag. *T*
h.. Pressure and shear stress are two examples of force per unit area. *T*
i. In the absence of other forces, water flows from low pressure to high pressure. *F*
j. When a fluid is cooled from above and become unstable the heat flux to depth that is transported by the fluid is termed convective heat flux. *T*
k. Evaporation of water from the surface of a lake causes the remaining surface waters to warm. *F*
l. An object that floats on water on Earth may sink if the gravitational acceleration is changed. *F*
m. The Doppler Effect implies that the frequency of the sound an observer hears changes if the observer or the sound source are moving relative to each other. *T*
n. The density of water is approximately $1 kg/m^3$. *F*
o. Two beads of the same material are sinking in a fluid each at its own terminal speed. The larger of the two will sink faster. *T*

Multiple choice questions (6pts each):

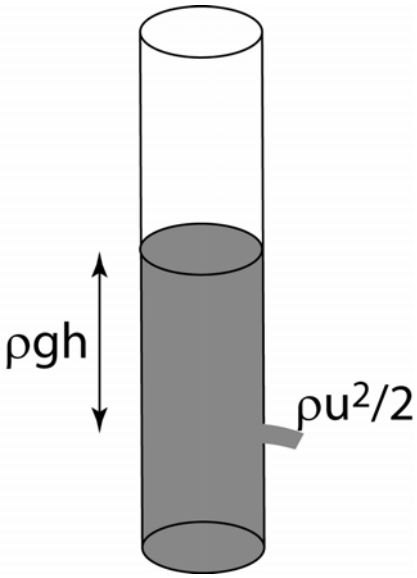
1. The no slip condition means that:
   a. Wind over land is faster 10m above bottom than 1cm above bottom.
   b. Currents in the ocean are faster 10m above bottom than 1cm above bottom.
   c. A coffee cup will eventually come to rest after vigorous mixing.
   d. All of the above.

2. On the moon, pressure on the bottom of a milk carton is:
   a. Larger than on earth
   b. Smaller than on Earth.
   c. Equal to that on Earth.
   d. Zero.

3. An object is unstable when:
   a. Its center of gravity and buoyancy are close.
   b. Its center of gravity and buoyancy are far.
   c. Its center of buoyancy is above its center of gravity.
   d. Its center of gravity is above its center of buoyancy.

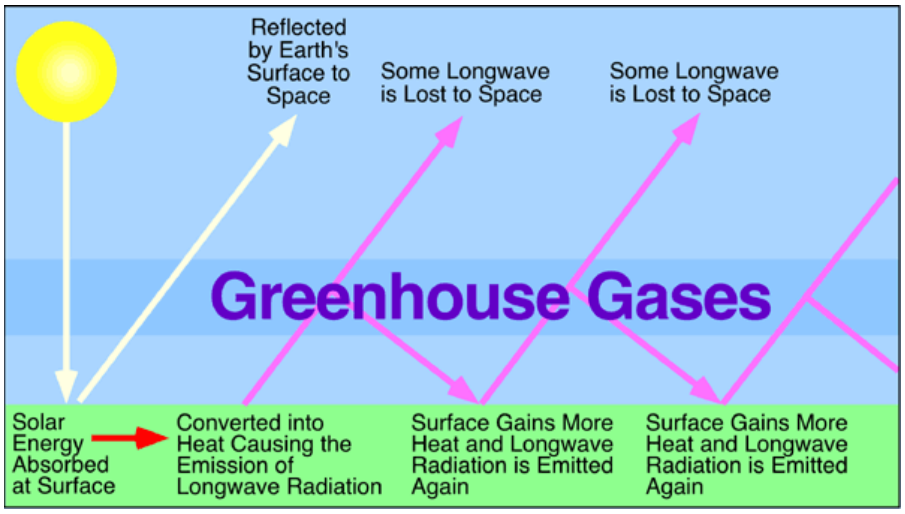
Please provide short answers to the following questions (5pts for questions associated with each picture):

1. Below is an illustration of an experiment you did in the lab. Does the speed of the water vary with the water height? Does it vary with the size of the hole?



The speed of the water does vary with the water height as the pressure at the hole within the container. The size of the hole does not matter as long as it is large enough that friction does not provide major damping. In the lab with the tubes we used the size of the hole did not matter.

2. Explain what phenomenon is illustrated in the figure below. What are some of the implications for the inhabitants of the Earth?



*The phenomenon illustrated is the **greenhouse effect**. Gases and water vapor within the atmosphere causes outgoing radiation to be reflected back to Earth. This effect results in the Earth being significantly warmer (and thus hospitable to living organisms) than it would have been had it no green house gases. Differences in temperature between day and night would be much more dramatic had the Earth not have an atmosphere.*