SMS-204: Integrative Marine Sciences II (2017).

Final examination (physics part)

Name:

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 log floats on fresh water (ρ =1 g cm^{-3}) with 1/6 of its volume outside the water. What is the density of the log in kg m^{-3}?

Based on Archimedes' principle, the log displaces a volume of water that has a mass that equals its own mass: V_displaced x 1000= V_log x ρ_log. The volume of displaced water = volume of the log below the surface.

But we know that 5/6 of the log is submerged. Hence:
→ V_diplaced/ V_log=5/6 →ρ_log = 5/6 x 1000=833.333kg m^{-3}

2. The ocean's volume is approximately 328,000,000 cubic miles. What is the ocean's volume in cubic kilometers (1 mi =1.6093 km)? Given that the ocean is about 70% of the Earth's surface area and that the Earth's radius is 6400km, what is the average depth of the world's ocean (assume the ocean to be rectangular)? The surface ocean temperature is ~15°C. If we heat it by 1°C will the volume of the oceans increase, decrease or stay the same? (in case you need it, the surface area of a sphere = $4\pi R^2$).

328,000,000$miles^3$=328,000,000(1.6093 km)^3=$1.37\cdot10^9 km^3$.
Earth's surface area: $4\pi R^2=5.15\cdot10^8 km^2$.
Ocean's surface area is 70% of Earth's surface area=$0.7\cdot5.15\cdot10^8 km^2=3.6\cdot10^8 km^2$.
Ocean mean depth=volume/surface area=3.79km.
Since water expands when we heat it, the volume of the ocean will increase if we warm the surface.

3. A whale swims at a constant speed while feeding on plankton.
   a. How many cubic meters of water enter the open mouth (50,000cm^2 area) of the whale each minute as it swims through the water at 200 cm s^{-1} (provide answer in MKS)?
   b. How many plankton can the whale ingest per second if the plankton concentration is 0.002 plankton per cm^3 (provide answer in MKS)?
   c. Each plankton provides 2 Calories to the whale. How many Calories does the whale ingest each day?

   a. ***50,000 $cm^2\cdot200$ cm s^{-1}=10,000,000 cm^3 s^{-1}= 10 m^3 s^{-1}=600 m^3 min^{-1}***
   b. ***10,000,000 cm^3 $s^{-1}\cdot0.002$ plankton cm^{-3}=20,000 plankton s^{-1}***
   c. ***20,000 plankton $s^{-1}\cdot2$Calories $plankton^{-1}\cdot86400s$ $day^{-1}=3.46\cdot10^9$Calories day^{-1}***

4. Water is flowing through a wide fireman hose. The fireman hose is mated to a narrower garden hose in which the water keeps flowing.
a. How is the water speed different between the two hoses?
b. How is the pressure different between just before the connection area and just after it?
c. What physical principles did you need to invoke to answer part a? to answer part b?

a. ***Faster in the garden hose since the same volume flux needs to be passed in both (continuity principle).***
b. ***Pressure is lower in the garden hose (Bernoulli's principle).***
c. ***Continuity in (a) and Bernoulli in (b).***

5. Phytoplankton, photosynthetic microorganisms, are observed to have many different shapes. Some scientists think that shape makes a difference in their ability to stay in the near-surface sunlit zone of the oceans. Based on what you learned in class, will their sinking speed increase, decrease or stay the same as a sphere of the same mass and volume? Base your answer on what you learned about drag and the hydrodynamic regime these organisms are experiencing.

In general (when averaged over all orientations) their sinking speeds will be less than that of an equivalent sphere having the same mass and volume because they operate at low Reynolds number where the viscous drag dominates and is proportional to the surface area of the particle. Spheres have the minimal surface area to volume and thus will have the least drag.

6. A boat floats in the Dead Sea (density = 1.25 g cm^{-3}). How will the boat float if moved to a lake of the same temperature (higher, lower, the same)? How would the boat float if you throw all the life jackets off the boat (higher, lower, the same; life jacket's density is 0.5g cm^{-3})?

The boat will float lower, or sink deeper as a larger volume of water will be displaced to equal to the mass of the boat. If you through anything that weigh something out of the boat, the boat will weigh less and hence will float higher in the water.

7. You free dive to spearfish off your boat. You fill your lungs to capacity (4.5 liters) at the surface and jump in. At 20m you exhale 1 liter of air. Assuming you do not exhale any more, what will your lung volume be when you surface following the dive? (Ideal gas law: PV=nRT, atmospheric pressure~10^5Pa)?

At twenty meters the volume of the lungs is a third what it was at the surface (pressure tripled); thus, it is 1.5 liter. If 1 liter is exhaled, 0.5 liter is left in the lungs. When reaching the surface again this volume is tripled (the pressure reduced to a third) →the lung volume at surfacing is 1.5 liters.

True/False questions (2pts each):

a. Liquid water is denser than ice. T
b. An object whose center of gravity is below its center of buoyancy is unstable. F
c. A larger object on the Earth's surface feels a larger pressure than a smaller object. F
d. Solute flux equals the Mass flux of water times solute concentration. T
e. Some Microorganisms use jet propulsion as a mechanism to propel themselves. F
f. The no-slip condition implies that swimming organisms will *always* experience drag while swimming. T
g. Streamlining reduces pressure (rather than viscous) drag for high Reynolds number swimmers. T
h. Objects radiate heat according to their color. F
i. A solid object that sinks in warm seawater may float in cold seawater. Y
j. Force has a dimension of ML^2T^{-2}, in MKS its units are: Kgm^2s^{-2}. F
k. Conduction refers to passage of heat through contact. T
l. At high Reynolds number, viscosity is not a primary contributor to drag. T

Multiple choice questions (6pts each):

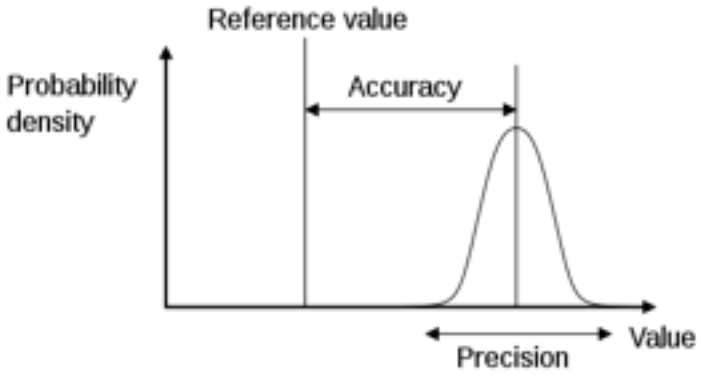
1. How can an organism under water change the buoyancy force acting on it?
   a. Change its mass (e.g. burn energy, get rid of waste products).
   b. Change its own temperature (e.g. work harder).
   c. Change its own volume (e.g. drink ambient fluid and expand).
   d. All of the above.

2. You are asked to measure the volume flux of the Penobscot. Which measurement will you conduct (circle all that apply)?
   a. water depth;
   b. water temperature;
   c. water speed;
   d. water pressure;
   e. width of the river;

3. You are asked to predict the pressure at the bottom of a lake. Which of the following you will need to know (circle all that apply)?
a. water depth;
b. water temperature;
c. water volume;
d. water density;
e. lake size;

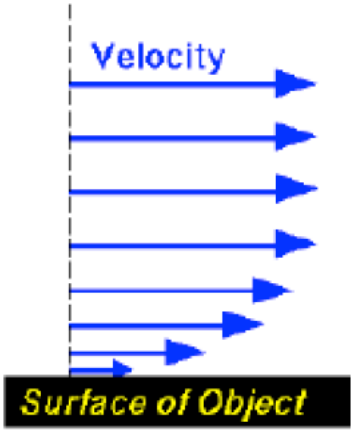
Please provide short answers to the following questions (6pts for questions associated with each picture):

1. How is the following graph related to concepts associated uncertainties? What is the difference between these concepts? Which is more difficult to deal with?



Uncertainties can come from both finite precision (for example of an instrument) or from a bias (accuracy). Precision relate to how close subsequent measurements are while accuracy to how close you are to the true value. Measurement may be inaccurate, for example, if the instrument is not well calibrated. Accuracy is harder to deal with because it is most often unknown (obtainable through calibration). In addition, precision uncertainties can be reduced by repeated independent measurements. Uncertainties due to accuracy cannot be reduced by repeating measurements with the same instrument. They can be reduced using different instruments all of which are independent from each other.

2. Explain what phenomenon is illustrated in the figure below. What is the physical principle causing it? What is its most important implication to swimming organisms?



The phenomenon illustrated is the no-slip condition, whereby fluid near an object must flow with the object. It is due to molecular and turbulen viscosity (which causes lateral diffusion of momentum). The implication for a swimming organism is that it will always experience drag as the water right next to it must move with it (and hence he has to spend energy to do it)..