SMS-204: Integrative Marine Sciences II (2008).

Answers to 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 1/4 of its volume outside the water. What is the density of the log in kg m^{-3}?

Log's weight: $V\rho_{log}g$. Buoyancy force acting on log: $¾V\rho_{water}g$
Where V is the log's volume and ρ denotes density. In equilibrium both buoyancy force and weight are equal → $¾V\rho_{water}g = V\rho_{log}g$ → $\rho_{log}=¾\ \rho_{water}=¾$ g cm^{-3}=750kg 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)?

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.

3. A whale swims at a constant speed while feeding on plankton.
   a. How many cubic meters of water enter the open mouth ($5m^2$ area) of the whale each minute as it swims through the water at 2 m s^{-1}?
   b. How many plankton can the whale ingest per second if the plankton concentration is 2,000 per m^3?
   c. Each plankton provides 2 Calories to the whale. How many Calories does the whale ingest each day?

a. $5\ m^2\cdot2\ m\ s^{-1}=10\ m^3\ s^{-1}=600\ m^3\ min^{-1}$
b. $10\ m^3\ s^{-1}\cdot2{,}000$ plankton $m^{-3}=20{,}000$ plankton s^{-1}
c. 20,000 plankton $s^{-1}\cdot2$Calories plankton$^{-1}\cdot86400$s day $^{-1}=3.46\cdot10^9$Calories day^{-1}

4. When you reduce the opening of a garden hose it squirts farther than when you don't. Why? Extra credit (2pts): How is it different from reducing the opening of the faucet the garden hose is connected to at its other end?

The faucet controls the volume flux into the hose. If we constrict the opening by the end of the hose the water has to move faster in the constriction by continuity (same flux of water as in other sections of the hose). Pressure builds up within the hose initially (very fast) when we put our thumb in front of the opening and once adjusted the volume flux is the same as when we did not constrict the opening. This pressure counters the extra drag associated with the constriction. There is a point where the pressure is high enough in the hose to reduce the flux of water coming out of the faucet, which will result in a reduction of volume flux out the hose. Finally, if we are able to plug the hose no water will come out.

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. Describe the three mechanisms of heat transfer. Using a marine organism of your choice, provide examples of these mechanisms at work influencing how it gains or loses heat.

Radiation: transfer of heat by photons.
Conduction: transfer of heat through contact.
Convection: transfer of heat through fluid motion.
Radiation warms a sea lion basking in the sun on the Oregon coast as well as cools him through infra red emission.
Conduction cools the sea lion as it swims in the ocean.
Convection causes water close to its skin to move upward replacing it by cold water and thus accelerating the loss of heat.

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 10m 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 ten meter the volume of the lungs is half what it was at the surface (pressure doubled); thus it is 2.25. 1 liter is exhaled, 1.25 is left in the lungs. When reaching the surface again this volume doubled (the pressure halved) →the lung volume at surfacing is 2.5 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. A blue object absorbs blue wavelengths. F
e. Solute flux equals the Mass flux of water times solute concentration. T
f. Some Microorganisms use jet propulsion as a mechanism to propel themselves. F
g. The no-slip condition implies that swimming organisms will *always* experience drag while swimming. T
h. Streamlining reduces pressure (rather than viscous) drag for high Reynolds number swimmers. T
i. Objects radiate heat according to their color. F
j. Light and sound wave both change speed as they move from air to water. T
k. To determine the pressure at a given depth in a fluid we need to know the gravitational acceleration. T
l. A solid object that sinks in warm seawater may float in cold seawater. T
m. Force has a dimension of ML^2T^{-2}, in MKS its units are: Kgm^2s^{-2}. F
n. Conduction refers to passage of heat through contact. T
o. 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 volume (e.g. using musculature).
   c. Change its temperature (e.g. work harder).
   d. All of the above.

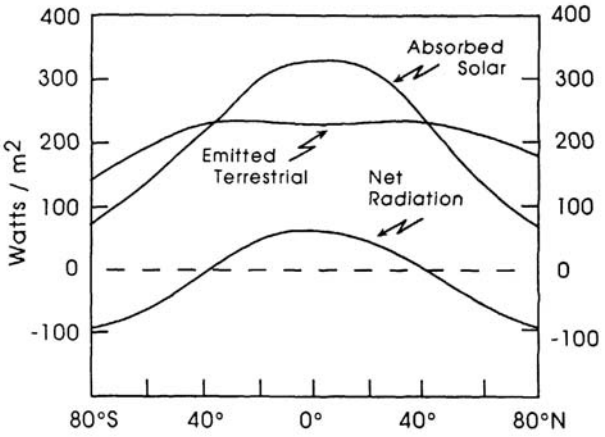
B. You are asked to measure the volume flux of the Penobscot. Which measurement will you conduct (circle all that apply)?

a. water depth;
b. water temperature;
c. water speed;
d. water pressure;
e. width of the river;

3. The drag force in low Reynolds number on a sinking particle is proportional to:
   a. Fluid density (ρ).
   b. Square of the diameter (D^2).
   c. Viscosity of the fluid (μ). $F=3\pi\mu DW$, e.g. homework 4, 5 and movies.
   d. b and c.
   e. a, b and c.

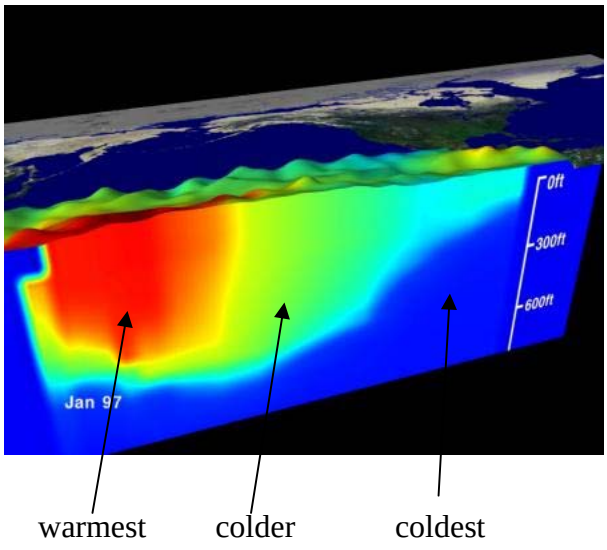
Please provide short answers to the following questions (5pts for questions associated with each picture):

1. How is the following graph related to concepts associated with the Earth heat balance? How can we explain the Polar Regions not getting continuously colder given the data in this graph?



The graph provides the zonal distribution of absorbed solar and emitted infrared radiations and the different between them. The reason the polar regions do not get colder despite the net radiation pattern is that atmospheric winds and ocean currents transfer heat from equator to poles.

2. Below is a figure of the temperature distribution in the upper ocean along the Equatorial Pacific. Assuming it reflects the density structure as well, how would you expect it to be if no force were acting on the fluid other than gravity? Extra credit (2 pts): What is a likely process giving rise to this observed distribution?



When no forces other than gravity act the fluid is layered according to density with no horizontal changes in density. The process causing the observed distribution is the wind stress along the equator piling warm surface waters on the western side of the Equatorial Pacific. When these winds ease (El nino) the warm waters to the west rush to the East with many consequences you will learn about in future classes.