SMS-204: Integrative Marine Sciences II (2014).

Final examination (physics part)

Name:

Please answer all questions (total time 50min): Please provide a short 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. You free dive to spearfish off your boat. You fill your lungs to capacity (4 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 10m pressure approximately doubles and hence your lung capacity is 2L. You exhale a liter and you have 1L left. Coming back to the surface pressure halves and volume will therefor double, resulting in 2L of air in the lungs.

2. You are fishing with a net that has an area of $10m^2$ in calm water. Your boat is steaming at 50cm/s:
   A. How much water volume flows through your net per hour?
   B. If the water density is $1.02g/cm^3$, how many Kg's of water flow through the net in 1 minute?
   C. If the density of fish is 1 every m^3, how many will you catch in an eight hour workday?

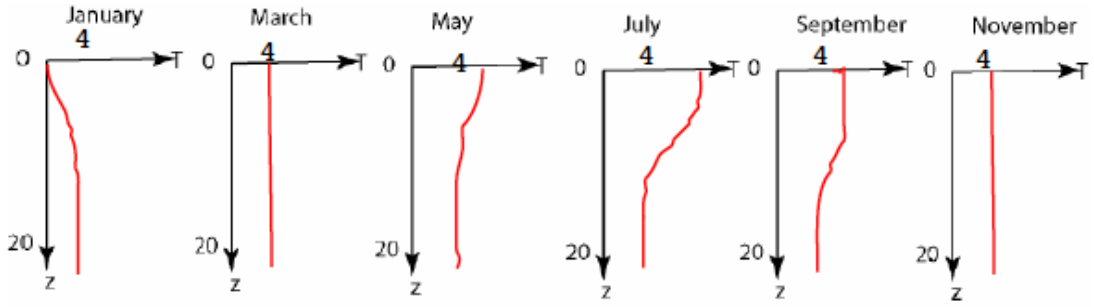
Volume flux: 50cm/s x $10m^2$ = 0.5 m/s x $10m^2$ x 3600s/hr = 18,000 m^3/hr
Mass flux: 1.02g/cm^3 x 50cm/s x $10m^2$ = 1020 Kg/m^3 x 0.5m/s x $10m^2$ x 60s/min = 306,000 Kg/min
Fish catch: 1/m^3 x18,000 m^3/hr x 8hrs/workday = 144,000fish/workday

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

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 infr 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.

4. Describe how streamlining affects drag at low and high Re numbers compared to a sphere of the same volume.
At low Re numbers drag is dominated by viscous drag. Since streamlining involve an increase in surface/volume, it will increase drag compared to a sphere. At high Re, pressure drag dominates, and streamlining will significantly decrease pressure drag while increasing a little the viscous drag. The net effect is reduction of drag.

5. Plot likely temperature profiles (T-temperature as function of depth, Z) for a lake in Maine (maximal 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's water is 20°C and the minimal is 0°C just below the ice, the ice reaches a temperature of -10°C and 1m thickness. Assume 0m depth denotes the surface of the water. Remember: fresh 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 reached 4°C it restratifies.
3. Deep waters are denser (hence colder) than surface waters except when waters are less than 4°C in which case the deep waters are warmer.
4. Liquid water in the lake cannot have a temperature less than 0°C

6. You are asked by the Environmental Protection Agency to measure the amount of fecal bacteria that are transported downstream by the Penobscot River near Bangor. How would you go about determining the transport of these bacteria downstream? What properties do you need to measure? Provide an example of the units for bacterial transport down the river (that is their flux)?
Measure: speed of water, cross-section of river, concentration of bacteria (number or weight per volume).
The flux of bacteria = mean water speed x cross-section of river x concentration of bacteria in units of number s^{-1}

7. An iceberg is floating in the ocean. Its density is 0.97 g cm^{-3} while the density of the ocean water is 1022 kg m^{-3}. How much of the iceberg's volume is *above* the water surface (give you answer in percent)?
By Archimedes' principle the mass of the iceberg equals to that of the water it displaces: $970 kg\ m^{-3} \times volume_{displaced} = 1022 \times volume_{iceberg} \rightarrow volume_{displaced}/volume_{iceberg} = 0.95$

$Volume_{above\ water} = volume_{iceberg} - volume_{displaced} \rightarrow Volume_{above\ water} / volume_{iceberg} = \mathbf{5\%}$

True/False questions (2pts each):

1. Liquid water is least dense near 4°C. F

2. Buoyancy force acting on an immersed object is larger in the ocean compared to a lake. T

3. Flagella is effective for micro-organisms because it allow them to glide. F

4. Gravitational force acting on an immersed object is larger in the ocean compared to a lake. F

5. In the absence of other forces, water flows from low to high pressure. F

6. The no-slip condition implies that at high Re number organisms cannot glide. F

7. Two particles with the same density are settling in a fluid. The largest will sink faster. T

8. The density of liquid water is approximately 1000Kg m^{-3}. T

9. Units of pressure in MKS are equivalent to Kg m^{-1} s^{-2} T

10. The hotter an object the longer the wavelength or the radiation it emits. F

11. The median is the 50^{th} percentile. T

12. A stable submerged object is one for which the center of buoyancy is above the center of gravity. T

13. Condensation of water vapors to form drops cools the atmosphere. F

Multiple-choice questions (6pts each):

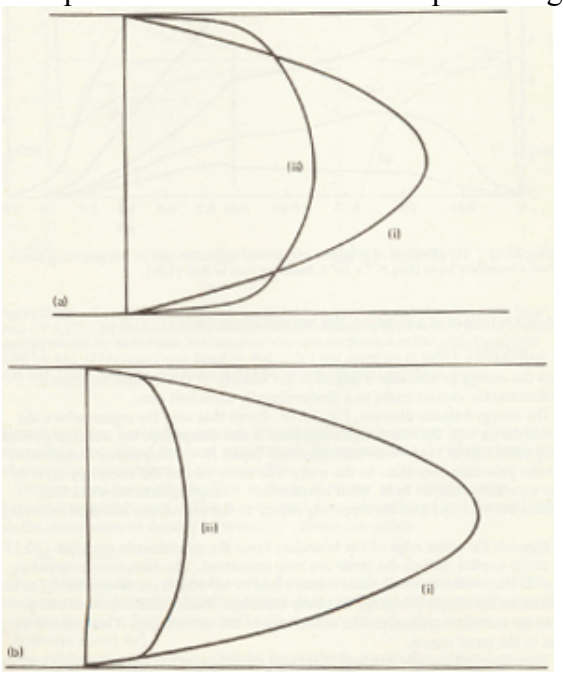
1. The coldest day of the year:
a. Is near the shortest day of the year.
b. Is near the day when the most net heat is lost.
c. Is near the day when least net heat is lost.
d. Is near the day when most NIR is emitted.

2. When swimming at large Re:
a. Drag increases linearly with viscosity.
b. Drag increases linearly with the square of velocity.
c. Drag increases linearly with size.
d. All of the above.

3. Radiative heat transfer:
a. is ineffective in empty space.
b. transfers heat through contact.
c. increases in water compared to air.
d. None of the above.

Please provide short answers to the following questions (7pts for questions associated with each picture):

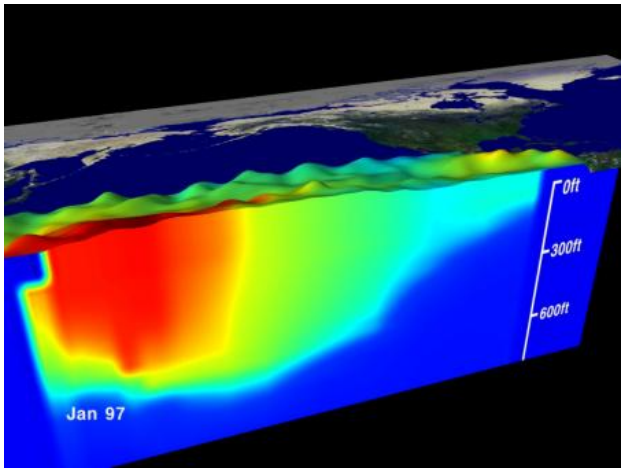
1. What is the difference between the two flows depicted in this picture? Which will transport more fluid for the same pressure gradient?



The two mean flows depicted in each of these figures are those of a fluid flowing in a pipe. One is turbulent (the one with the small mean BL) the other is laminar.
In the top panel the shape of the flows are depicted.
In the lower one we look at the actual velocity distribution.

The laminar will transport more fluid for the same pressure gradient as the turbulent one is associated with more dissipation of energy (more loss of momentum to the boundary).

2. What situation is depicted in this picture? If the wind were to stop, what will happen to the dark fluid?



The situation depicted is associated with la nina, that is the normal case in the equatorial pacific where winds blowing from East to West pile the warm waters at the Western side of the equatorial Pacific which are replaced by cold water to the East. If the wind stopped blowing the cold water will flow below the warm water and a stratified water column all along the equator will result (red on top, then green and blue below).