SMS-204: Integrative Marine Sciences.

Mid-term examination (physics part)-answer

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. Italics numbers in brackets indicate the number of fully correct answers out of 8 students.

1. A submarine that weighs 17,500Kg in air and has a volume of $20m^3$ floats in a harbor. How much of its volume do we need to flood in order to just begin sinking it in fresh water with density $1000kg/m^3$? (*2/8*)

By Archimedes principle it will just begin sinking when its density matches that of water.
Let's assume that we flood V volume with water and lets neglect the density of air (which is approximately 1000 times less than water)

Density of partially flooded submarine= $(17500+V*1000)/20 = 1000\ kg/m^3$
→ $V=(20000-17500)/1000=2.5\ m^3$

We need to flood $2.5m^3$ for the submarine to start sinking.

2. A whale swims at a constant speed while feeding on plankton. *(5/8)*
   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 5 m s^{-1}?
   b. How many zooplankton can the whale ingest per second if the zooplankton concentration is 1 per liter?
   c. If each zooplankton provides the whale with 2 calories, how many calories does the whale ingests in a day?

a. Assuming all the water enter the mouth, the volume water flux = $5m^2$ x 5 m s^{-1} = $25m^3\ s^{-1}$. Per minute this represent a flux of 25 x 60 =150 $m^3\ min^{-1}$.
b. There are 1000L in one m^3. The flux of zooplankton = 1/liter x 1000liter/$1m^3$ x $25m^3\ s^{-1}$ = 25000 zooplankton per second.
c. Calories per day= 2cal/zooplankton x 25000 zooplankton eaten per second x 24 x 3600 seconds/day = 4.32×10^9 calories/day

3. In Maine the shortest day of the year is in late December yet the coldest day of the year (on land and in the surface waters) is close to the beginning of March. Why? *(4/8)*

The rate of cooling is largest in late December, but until late-February beginning of March there is still net cooling happening (averaged over a day, heat is lost from the land or ocean into space) resulting in lower temperatures than in late December.

4. The following water vessel contains water. How is the hydrostatic pressure distributed within this vessel as function of depth (feel free to ignore the atmospheric pressure)? Sketch a graph if you find it useful. *(4/8)*

The pressure increases monotonically with depth. P=density x g x h, where g is the acceleration of gravity and h the distance from the top of the vessel.

5. You are asked by the US Geological Survey to measure the amount of mercury that is transported downstream by the Penobscot River near Bangor. How would you go about determining the transport of mercury downstream? What properties do you need to measure? Provide an example of the units for mercury transport (flux)? *(1/8)*

To obtain the transport of mercury we need to measure the water transport (m^3s^{-1}) and the concentration of mercury in the water (gr m^{-3}, mol $liter^{-1}$). An example of mercury flux units would be: gr s^{-1} or mols day^{-1}

6. Why is a deep snorkel not a practical tool for sub-surface diving? *(7/8)*

The hydrostatic pressure at depth is larger than at the surface, squeezing air out of the lungs; being connected to the surface through the snorkel means that the pressure in the lungs would be similar to that of the atmosphere while the pressure on the lungs from outside is the local hydrostatic pressure. This causes a net force on the lungs to collapse that can only be countered by actively (muscle power) opening the chest cavity. The only way to counter that effect is to provide pressurized air to the lungs.

7. What is the Re number? What is its dimension? What is it useful for? *(5/8)*

The Reynolds number (Re) is a dimensionless number representing the ratio of the product of velocity and length to the kinematic viscosity. Re helps to distinguish between different hydrodynamic regimes. When it is low viscous forces dominate while inertial forces dominate when it is large. The flow is laminar, that is predictable, dominated by viscosity and slowly varying when

the Re is small. The flow is turbulent, that is unpredictable, varying in time and space when the Re is large.
Re is important when we want to analyze a flow (e.g. that due to a swimming organism) or build a model of a flow with different length scale (e.g. a boat in the lab). By matching the Re (hydrodynamic similarity) we can study on a model and extrapolate to the real body.

True/False questions (2pts each):

a. In water, pressure increases with depth. T *(8/8)*
b. Light is attenuated less than sound in the oceans. F *(4/8)*
c. Force=work / distance T *(6/8)*
d. A red objects absorbs preferentially in the red. F *(5/8)*
e. A solid object completely immersed in cold water (10°C) experience more upward buoyant force than when it is immersed in warm water (20°C). T *(5/8)*
f. An object that floats on water may sink if its shape is changed. T *(4/8)*
g. The no-slip condition implies that for a pipe full of moving fluid the fluid near the pipe wall flows less fast than at the pipe's center. T *(7/8)*
h. A boat is most stable when its center of gravity is as low as possible below its center of buoyancy. T *(6/8)*
i. The Reynolds number of a swimming bacterium is much smaller than that of a Tuna fish. T *(8/8)*
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 (8/8)
k. Evaporation of water from the surface of a lake causes the remaining surface waters to cool down. T (8/8)
l. An example for a unit of force is Kg m s^{-1} F *(4/8)*
m. The Doppler Effect implies that the frequency of the sound an observer hears changes if the observer or the sound source are moving at the same speed and direction. F*(5/8)*
n. For the same volume, material, internal temperature and outside conditions, a round object looses less heat than any other shaped object. T *(4/8)*
o. Two beads of the same material ARE sinking in a fluid at constant speed. The larger of the two will sink faster. T *(8/8)*

Multiple choice questions (6pts each):

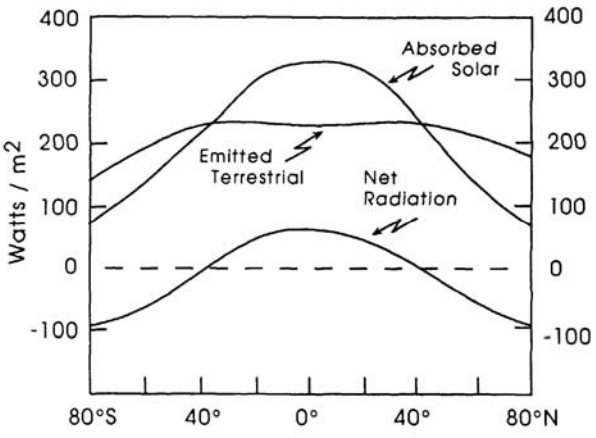
A. When we calculate the pressure at the base of a fluid column: *(5/8)*
a. the gravitational acceleration does not matter.
b. the height of the column does not matter.
c. the density of the fluid does not matter.
d. none of the above.

B. You are asked to evaluate whether a boat can float? What do you need to measure? *(7/8)*
a. the weight of the boat;
b. the volume of the boat;
c. the viscosity of the water;
d. a and b;
e. a, b, and c.

C. Which of the following is not a high Re number swimming strategy? *(8/8)*
1. Jet propulsion
2. Appendage propulsion
3. Flagella propulsion

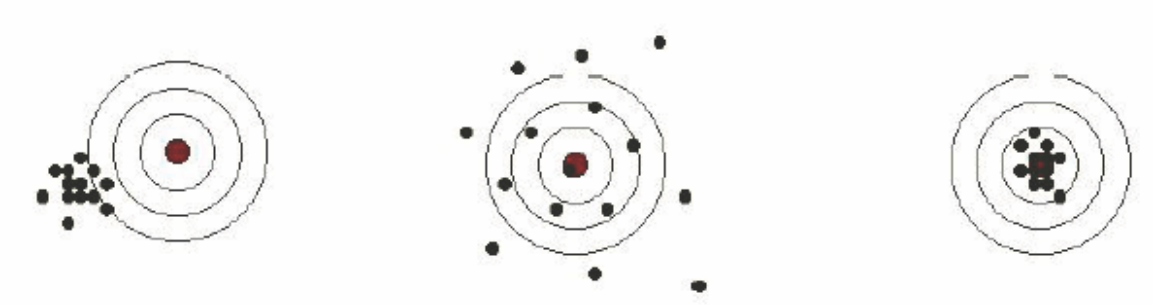
Please provide short answers to the following questions (5pts for questions associated with each picture):

1. Below is a graph providing the yearly average absorbed and emitted radiation by the earth as function of latitude. How come the difference between the two radiations (the net radiation) is not zero at each latitude? (Note it is approximately zero when summed over all latitudes). *(1/8)*



The reason for the difference is that heat is transported from the equatorial regions to the poles by atmospheric winds and ocean currents (advective heat flux). If that were not the case, the net radiative flux would be close to zero at each latitude, since radiation is the most likely means to gain or loose energy into space without fluid motion (conduction through air is a very inefficient heat fluxing process).

2. Use the concepts of accuracy and precision with respect to the cartoon below. *(7/8)*



Precise but not accurate. Accurate but not precise. Precise & accurate.