SMS-204: Integrative Marine Sciences II (2010).

Final examination (physics part)

Name:

Please answer all questions (total time 70min): 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. The ocean's volume is approximately 328,000,000 cubic miles. What is the ocean's volume in cubic meters (1 mi =1609.3 m)? 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)?

$328{,}000{,}000\,miles^3=328{,}000{,}000(1.6093\ km)^3=1.37\cdot10^9 km^3=1.37\cdot10^{18}m^3$ 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.

2. A whale swims at a constant speed while feeding on plankton.
a. How many cubic meters of water enter the open mouth ($3m^2$ area) of the whale each minute as it swims through the water at 0.5 m s^{-1}?
b. How many plankton can the whale ingest per minute if the plankton concentration is 30,000 per m^3?
c. Each plankton provides 2 Calories to the whale. How many Calories does the whale ingest each day?

- ***a. $3\ m^2\times0.5\ m\ s^{-1}=1.5\ m^3\ s^{-1}=90\ m^3\ min^{-1}$***
- ***b. $90\ m^3\ min^{-1}\times30{,}000$ plankton m^{-3}=2,700,000 plankton min^{-1}***
- ***c. 2,700,000 plankton $min^{-1}\times$2Calories plankton$^{-1}\times$1440min day^{-1} $=7.78\cdot10^9$Calories day^{-1}***

3. Assume that you have a U-shaped, hollow tube with Karo syrup (density 1250 kg m^{-3}) in it such that both arms are half filled. What would happen if you added a given mass of water (1000 kg m^{-3}) into the first arm of the manometer? If the cross-sectional area of the manometer is 2 cm^2 and the amount of water added is 10ml, what will be the height difference between the two arms of the manometer (feel free to add a sketch)??

The fluid in both arms will rise. The fluid in the arm where water was added will be higher than in the other arm. The pressure at the base of the water has to be equal to the pressure at the same depth at the other branch. The height of the water is 5cm ((10ml=10cm^3)/2cm^2). Lets' call the height of the karo at the other side y. Given that the pressure just below the water is the same as that at the other side (the fluid has the same density and height up to this point):

$5cm*1000kg/m^3=y\times1250kg/m^3$ → y=4cm.
→ The difference in height will be 5-4=1cm.

4. How do latent heat of evaporation and fusion compare in magnitude? Where does the energy come from and where does it flow to when: 1. Water condenses to form clouds? 2. Water evaporates from the ocean's surface? and 3. Water freezes on a lake's surface?

Latent heat of evaporation is much larger than that of fusion (by about a factor of 7). When water condenses into clouds: heat from condensation warms the atmosphere around the water. When water evaporates from the ocean's surface: heat flows from atmosphere and water below the surface and is used to evaporate water. When water freezes on a lake's surface heat is released to water below and atmosphere above.

5. A boat floats in the Dead Sea (density = 1.25 g cm^{-3}). How will the boat float if moved to a lake (higher, lower, the same)? How would the boat float in the Dead Sea if you throw all the bedding off the boat (higher, lower, the same; bedding density is 0.05g cm^{-3})?

Since the density of the lake is lower than the Dead Sea, the boat will float less high. Since the bedding is load taken of the boat, the boat will float higher (its mass is reduced).

6. Describe how streamlining affects drag at low and high *Re* numbers.

At low Reynolds number a streamlined and non-streamlined objects have similar pressure drag, however the viscous drag is proportional to their surface area. For bodies with similar cross section, a sphere has the smallest surface to volume ratio and thus experience less viscous drag. At high Reynolds number a streamlined object experience negligible pressure drag while a sphere, being a blunt object, experience pressure drag. The contribution of the pressure drag to the blunt object is larger than that of the added viscous drag experienced by the streamlined object resulting in a higher total drag for the non-streamlined object at high Reynolds numbers.

7. You dive in order to retrieve an engine that fell off your boat in a 10m deep lake. The engine weighs 35Kg in air and has a volume of 5 liters. What size of buoyancy bag do you need (in m^3) to inflate to lift the engine off the bottom (you can assume the water density is 1g cm^{-3} and air density to be negligible, and the buoyancy bag to have the same density as the water.)?
(A "buoyancy bag" or "lift bag" is a bag that can be filled with air & attached to a submerged object to provide it additional buoyancy or lift to float it to the surface with minimal effort from the diver)

The objects weight in water equals it weights in air, 35Kg, minus the weights of the water it displaces, 5Kg, hence 30Kg. a 30 liter lift bag will provide the necessary buoyancy.

True/False questions (2pts each):

a. A solid object completely immersed in cold water (10°C) will experience more upward buoyant force than when it is immersed in warm water (20°C) T
Cold water has a higher density than warm water, thus it creates higher buoyancy
b. An object whose center of gravity is below its center of buoyancy is stable. T
c. A larger object on the Earth's surface feels a larger pressure than a smaller object. F
d. A red objects absorbs preferentially in the red. F
e. Momentum flux equals the Mass flux of water times water density. F
f. Some Microorganisms use cillia to propel themselves. T
g. The no-slip condition implies that near the river bed velocity is increased compared to further up in the water column. F
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 reduce speed as they move from air to water. F
k. To determine the pressure at a given depth in a fluid we need to know the gravitational acceleration. T
l. An object that floats on water on Earth today may sink if the gravitational acceleration of the Earth were to change. F
m. Energy has a dimension of ML^2T^{-2}, in MKS its units are: Kgm^2s^{-2}. T
n. Conduction refers to passage of heat through fluid motion. F
o. At low Reynolds number, viscosity is not a primary contributor to drag . F

Multiple choice questions (6pts each):

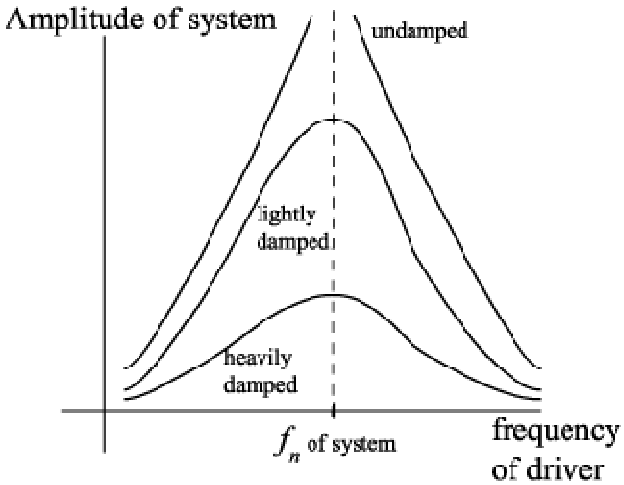
1. How can an organism in water insure that it is aligned relative to gravity?
   a. Have a lot of weight
   b. Have a lot of buoyancy.
   c. Have a separate center of mass from center of buoyancy.
   d. Have the same center of mass as its center of buoyancy.

2. 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;

3. Total internal reflection:
   a. Is associated with the occurrence of a sound channel.
   b. Can occur when a wave moves from slow to fast medium.
   c. Is associated with the lateral bounds of Snell's cone.
   d. All of the above.

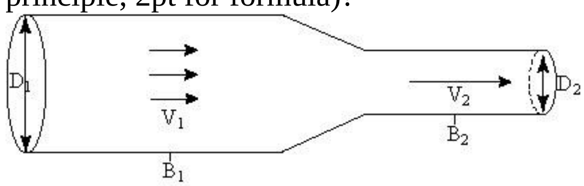
Please provide short answers to the following questions (5pts for questions associated with each picture):

1. What phenomenon does this figure represent?



The phenomenon is resonance. When we force a system with a periodic forcing with a frequency near its natural frequency we get the strongest response.

2. What is the principle associated with fluid motion that is illustrated below (3pt for principle, 2pt for formula)?



Continuity: the fluid flux through a pipe (blood vessel) is equal along it,

$$v_1 \times \pi D_1^2/4 = v_2 \times \pi D_2^2/4$$