SMS-204: Integrative Marine Sciences II (2013).

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. An iceberg is floating on the ocean. Its density is 920 kg m^{-3} while the density of the ocean's water is 1030 kg m^{-3}. How much of the iceberg's volume is *above* the water surface (give you answer in percent)?

The displaced water should provide the buoyancy force that equals the weight of the iceberg: iceberg volume × 920 kg m^{-3} × g = displaced volume × 1030 kg m^{-3} × g
→ Displaced volume/iceberg volume = 920/1030 = 0.89
89% of the volume is under water and 11% of the volume is above the water.

2. You are asked by the US Geological Survey to measure the amount of sediments that is transported downstream by the Penobscot River near Bangor (sediment are measured in Kg/m^3 dry weight). How would you go about determining the transport of sediment downstream? What properties do you need to measure? Provide an example of the units for sediment transport?

Measure water velocity, sediment concentration, and cross sectional area.
Measure both velocity and concentration at several places within the cross section of the river to get a good estimate for the mean velocity and mean concentration.
The sediment transport is equals to [with dimensions in square brackets:
*mean velocity [L/T] * sediment concentration [M/L^3]* cross sectional area [L^2], in dimensions of mass per time [M/T], such as Kg dry sediment per second.*

3. The 'biological pump' refers to the removal of atmospheric carbon dioxide, fixed into organic matter by phytoplankton, by sinking of organic matter into the deep ocean. Some material sinks as carbonate and silica shells of micro-organism which have very complex shapes. Based on what you learned in class, will their sinking speed increase, decrease or be the same as spheres of the same mass and volume? Base your answer on what you learned about drag and the hydrodynamic regime these fragment are experiencing as they sink.

Since we are dealing with micro-organism, the associated Reynolds number of their cell wall material can be assumed to be very small ($Re<<1$). In that regime, drag is dominated by stress drag, and hence increases for non-spherical particles compared to spherical one (they have a larger-surface area/volume ratio), and hence such particles with sink slower to depth compared to spherical particles of the same density and volume.

4. The ocean's volume is approximately 330,000,000 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)?

Ocean's volume: $330{,}000{,}000 miles^3 = 330{,}000{,}000 (1.6093\ km)^3 = 1.37 \cdot 10^9 km^3$.
Earth's surface area: $4\pi R^2 = 5.15 \cdot 10^8 km^2$.
Ocean's surface area is 70% of Earth's surface area $= 0.7 \cdot 5.15 \cdot 10^8 km^2 = 3.6 \cdot 10^8 km^2$.
Ocean mean depth=volume/surface area=3.81km.

5. 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 $10\ m\ s^{-1}$?
b. How many zooplankton can the whale ingest per second if the zooplankton concentration is 1.5 per liter?
c. If each zooplankton provides the whale with 3 calories, how many calories does the whale ingests in a day?

a. $3\ m^2 \cdot 10\ m\ s^{-1} = 30\ m^3\ s^{-1} = 1800\ m^3\ min^{-1}$
b. $30\ m^3\ s^{-1} \cdot 1{,}500\ plankton\ m^{-3} = 45{,}000\ plankton\ s^{-1}$
c. $45{,}000\ plankton\ s^{-1} \cdot 3 Calories\ plankton^{-1} \cdot 86400 s\ day^{-1} = 1.17 \cdot 10^{10} calories\ day^{-1}$

6. You dive in order to retrieve a sunken treasure in a 10m deep lagoon. The treasure weighs 1200Kg in air and has a volume of $1\ m^3$. 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 1.0 $g\ cm^{-3}$ and air density to be negligible, and the non-inflated 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)

To make the treasure chest be weightless in the water, the combined density of the chest and air bags have to be the same as that of the surrounding waters:
$Density = mass/volume = 1200 Kg/(1m^3 + Volume\_of\_airbag) = 1.0\ g\ cm^{-3} = 1000 Kg\ m^{-3}$
$\rightarrow 1m^3 + Volume\_of\_airbag = \mathbf{1.2}\ m^3 \rightarrow Volume\_of\_airbag = 0.2\ m^3$

7. In Maine (and Florida) 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 in late February/beginning of March. Why?

While during the shortest day of the year, net heat flux is most negative (minimal incoming solar radiation per area due to Earth tilt), cooling continues until late February/beginning of March, that is the increase in day length due to lengthening of the day is still not sufficient to offset loss of heat, primarily to long wave radiation. By late February/beginning of March, we reach minimum temperature, when the net heat flux is zero.

True/False questions (2pts each):

a. For the same pressure gradient, a laminar flow will transport more fluid than a turbulent one. T
b. Pressure and stresses have the same units. T
c. A sinking submarine experience most of its drag due to viscosity and not from pressure. F
d. The earth loses the heat it absorbs from the sun mostly through radiation. T
e. From Bernouli's principle we deduce that within an decelerating fluid pressure increases. T
f. The no-slip condition implies that there is a boundary layer around a swimming fish. T
g. Pressure approximately doubles between the ocean's surface and 20m depth. F
h. The standard deviation of velocity has the same unit as velocity. T
i. Accuracy and precision are synonyms for how well we can replicate a measurement F
j. Viscosity is a major contributor to the drag experienced by a swimming tuna. F
k. density of water is approximately 1000Kg m^{-3}. T
l. A solid object completely immersed in fresh water will experience the same upward buoyant force as when it is immersed in sea-water. F
m. Energy is the capacity to do work. Work and energy have the same units. T

Multiple-choice questions (6pts each):

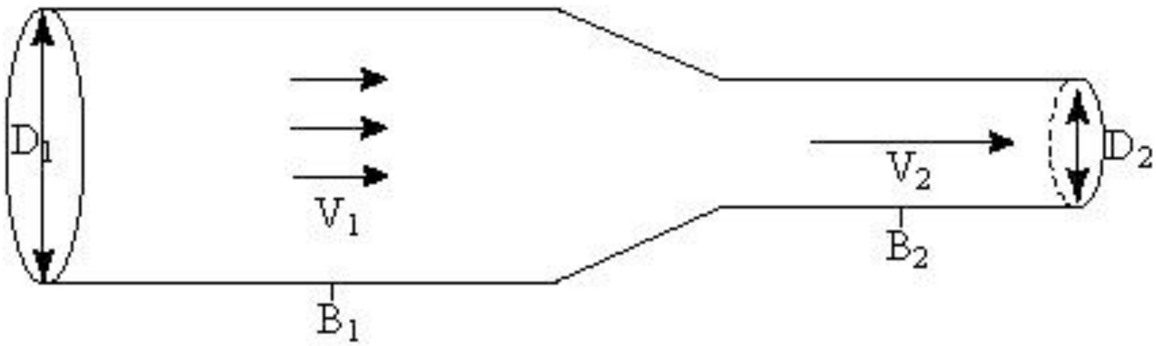
1. An object is unstable when:
a. Its center of gravity and buoyancy are close.
b. Its center of gravity and buoyancy are far.
c. Its center of buoyancy is above its center of gravity.
d. Its center of gravity is above its center of buoyancy.

2. How can an organism under water change the buoyancy force acting on it?
a. Change its volume (e.g. using musculature, taking in water).
b. Change its mass (e.g. burn energy, get rid of waste products).
c. Change its temperature (e.g. work harder).
d. All of the above.

3. To calculate the volume flux of blood in a vein, which are needed?
a. Mean blood speed.
b. Cross sectional area of the blood vessel.
c. Density of blood.
d. a and b.
e. a, b and c.

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

1. What is the principle associated with fluid motion that is illustrated below? How would you expect the pressure to change within this pipe?



The principle associate with this motion is continuity, which is basically the principle of mass conservation associated with highly incompressible fluids. It states that the same volume flux will be at any point along this pipe (volume flux = velocity x cross-sectional area). Given Bernoulli's principle (which assumes that viscous losses can be neglected) we will expect a higher pressure where the velocity of the fluid is smaller (B1) compared to where it is faster (B2).

2. Below is an illustration of Reynolds' experiment. What did he conclude from this experiment regarding laminar and turbulent fluid motions and the conditions under which they occur?

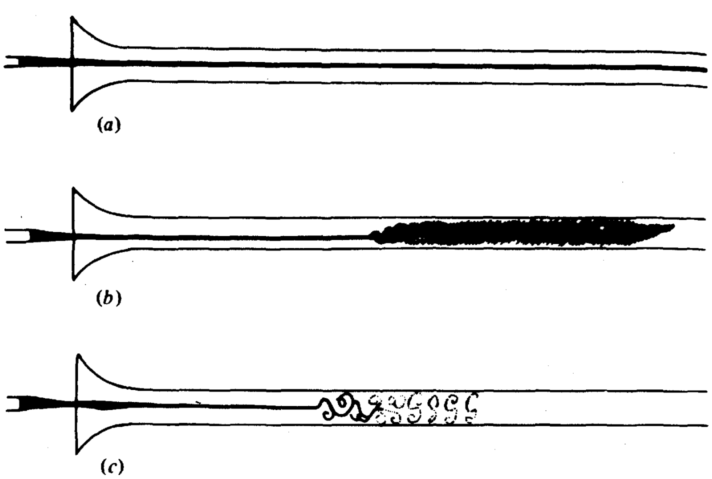


Fig. 9.2. Reynolds's drawings of the flow in his dye experiment.

Reynolds concluded that:

1. *Fluid with similar ratios of Re = {velocity x diameter of pipe x density/viscosity} have similar flows.*
2. *Turbulence is a threshold phenomenon. At a given Re value flow transition from stable to chaotic. Turbulent flows are associated with eratic motions and mixing.*
3. *Turbulence flow, when photographed appears made of coherent eddies (figure 9.2c).*

4. *Below the threshold Reynolds' number value, the flow was organized and straight (termed 'laminar', meaning 'layered').*