SMS-204: Integrative Marine Sciences II (2019).

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.

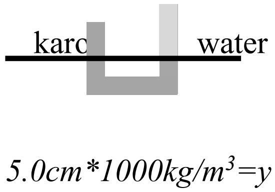
1. A person weighing 60kg is sitting in a boat that weighs 200kg floating on a lake.
a. How much water (in volume) does the boat+person displace?
b. The person decides to jump into the water. How much water does the boat displace now?
c. If the boat is transferred to the ocean (ocean density=1.02g/ml), will it float higher, lower, or stay with the same water level?
A floating object displaces its mass. Assuming the density of water is 1000kg m^{-3}, 260kg of water will be displaced which is equivalent to 260liters.

a. *After the person jumps, the boat will only displace 200liters.*
b. *The boat will float higher as less volume of water needs to be displace to provide an equivalent mass.*

2. You are asked by your supervisor at an EPA internship to measure the mass flux of methyl-mercury (a toxic contaminant) at a stream nearby at a certain time of the day (methyl-mercury concentration is typically reported in micro-gram per liter = mili-grams per m^3).
a. What measurements will you do ?
b. How will you used these measurements to obtain the mass flux of methyl-mercury?
c. What units will this mass flux have?

a. *Measure the average flow-rate (m/s), cross-section (m^2) and methyl-mercury concentration (nano-grams per m^3).*
b. *Methyl mercury flux = flow-rate x cross-section x concentration*
c. *mili-grams of methyl-mercury per second*

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 but the arm with water will end up higher. The height of the added water is $10cm^3/2cm^2$=5cm. Since at the position of the black line (and below) the same pressure should be in the fluid (otherwise the fluid will flow in the manometer) :

$5.0cm*1000kg/m^3=y*1250kg/m^3$ → y=4cm. Where 'y' denotes the height of the karo above the line. → The difference in height will be 5.0-4.0=1cm.

4. You free-dive to spearfish off your boat. You fill your lungs to capacity (4 liters) at the surface and jump in. At 20m 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 20m the pressure is 3 times that at the surface and hence the volume of air is 4/3 liters. Exhaling 1 liter 1/3 liter is left in the lung. Back at the surface the pressure is a 1/3rd than at 20m and the lung expand back to 1liter.

5. A jellyfish sinks at a constant speed while feeding on plankton.
a. How many cubic meters of water does it filter per minute through its tentacle ($0.05m^2$ area) if it sinks through the water at 0.05 m s^{-1}?
b. How many plankton can the jellyfish ingest per hour if the plankton concentration is 1,000 per m^3?
c. Each plankton provides 0.001 Calories to the jellyfish. How many Calories does the jellyfish ingest each day?

a. *0.05 m^2 x 0.05 m s^{-1} x 60 s/min = 0.15 m^3/min.*
b. *0.15 m^3/min x 1000 m^{-3} x 60min hr^{-1} = 9000 plankton/hr*
c. *9000 plankton/hr x 0.001 Calorie/plankton x 24 hr/day = 216 Calories*

6. You are asked to relocate a sunken boat to be used as an artificial reef. The boat's mass is 5,000Kg and the volume of its solid parts is $4m^3$. Assume the water density is 1.02g/ml. Approximately what minimal volume of an air bag should be attached to it so it can be lifted under water to be moved to its new location?
The net force on the boat is the difference of gravitational force and buoyancy:
F = (5000Kg - $4m^3$ x 1020 kg m^{-3})g = 920g (where g is the gravitational acceleration)
Neglecting the mass of the air bag we need to displace with the bag water which is equivalent to 920kg. 920kg/1020 kg m^{-3} ~ $0.9m^3$ to be able to just lift the boat.

7. Name the three mechanisms for heat transfer. Give one example for each that may be relevant to a marine organism?
Conduction, convection and radiation. Conduction is the heat loss or gain by transfer of heat from the water to all marine organisms. Convection involves the rising and sinking of water as heat changes the water density. Relevant to mixing of phytoplankton in the mixed layer during the winter . Radiation is the conversion of photons to heat. These occur for all absorbing organisms, such as algae in the surface ocean or seals basking in the sun.

True/False questions (13 questions, 2pts each):

a. Convection refers to passage of heat through contact. F
b. Algae are green because they absorb green light. F
c. In the absence of other forces, fluids flow from high to low pressure. T
d. A low Reynolds number swimmer will swim faster if it changes its shape to one that is more hydrodynamic (e.g. like a torpedo). F
e. Light and sound both have different speeds in air and water. T
f. The no-slip condition implies that water next to a fish moves at the fish's speed. T
g. Two solid beads of the same material are sinking in a fluid at constant speed. The larger will sink faster. T
h. To determine if an object will float in a fluid we need to know the gravitational acceleration. F
i. It is better to have accurate measurements than precise ones. T
j. Units of pressure in MKS are equivalent to Kg m^{-1} s^{-2} T
k. Evaporation of water from the surface of a lake causes the remaining surface waters to warm. F
l. A solid object completely immersed in oil will experience less buoyant force as when it is immersed in water (oil is less dense than water). T
m. Hydrostatic pressure in the bottom of a milk carton is higher on Earth compared to the moon (the gravitational acceleration is less on the moon) T

Multiple choice questions (3 questions, 6pts each):

1. The continuum hypothesis for fluids means that:

a. The fluid can be described as a deformable material with bulk properties that are constant on much larger scales than that of molecules.
b. The flow field does not have abrupt changes, that is, acceleration and other flow transitions are smooth.
c. Fluids continue to flow long after we stop the forces acting on it.
d. All of the above.

2. You are in your kayak in a lake and throw the anchor out.
As a result:

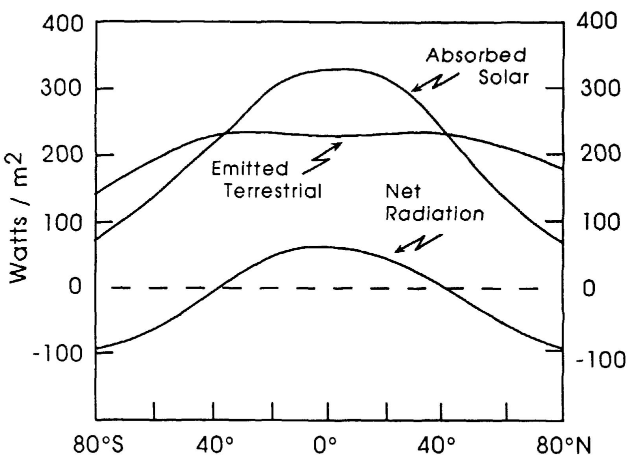
a. The kayak will rise (displace less water).
b. The kayak will sink (displace more water).
c. The lake level will stay the same.
d. The lake level will rise.

3. A consequence of Bernoulli's principle:

a. Fluid decelerates as it moves from low to high pressure.
b. Fluid accelerates as it moves from low to high pressure.
c. Mass is conserved along fluid flows.
d. Friction is not important.

Please provide short answers to the following questions (7pts each):

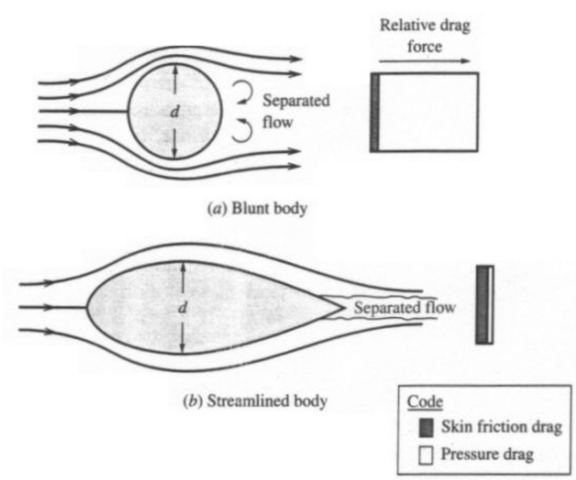
1. How is the following graph related to concepts associated with the Earth heat balance? How is it that the Polar Regions are not getting continuously colder given the data in this graph?



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 cartoon of different bodies in a flow. How do the different type of drag force on them vary from each other as a result of body shape? What regime (laminar vs. turbulent) is consistent with this image? How will the relative contribution to drag change in the other regime?



A blunt body has significant pressure drag which is reduced for a streamlined shape in a high Re flow depicted here. The streamlined shape will have more frictional drag for the same volume as it will have more surface area, yet this increase is much smaller than the reduction in pressure drag. The regime depicted is turbulent (high Re).

In the laminar regime (low Re) streamlining does not reduce drag as frictional drag dominate.