SMS-204: Integrative Marine Sciences II (2018).

Final examination (physics part), Version 1

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 wood log is floating on a river. Its density is 0.95 g cm^{-3} while the density of the river's water is 998 kg m^{-3}. How much of the log's volume is below the water surface (give you answer in percent)?
Based on Archimedes' principle, the log displaces a volume of water that has a mass that equals its own mass: V_displaced x 0.998= V_log x 0.95. The volume of displaced water = volume of the log below the surface.
→ V_diplaced/ V_log=0.95/0.998=0.952 → 95.2% of the log's volume is below the surface.

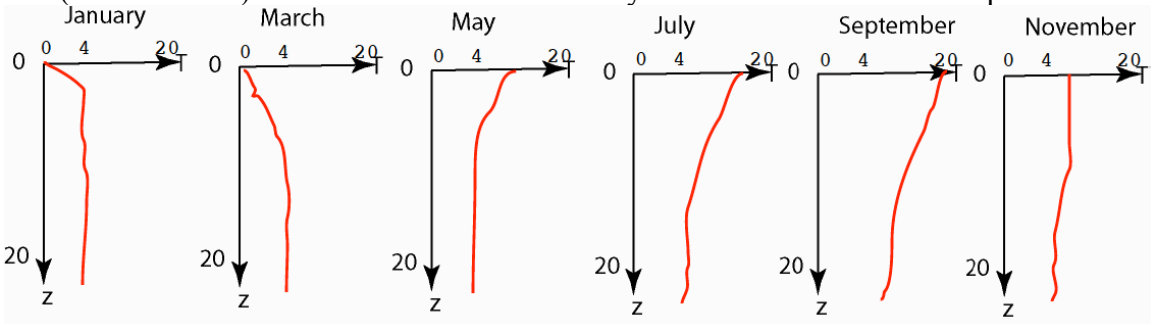
2. You are asked by your supervisor at a USGS internship to measure the volume flux of water at a stream nearby at a certain time of the day.
a. What measurements will you do and how will you use them to obtain the volume flux of water?
b. It turns out that the stream is a salmon run. What additional information will you need to obtain the salmon flux in the stream and how would you compute it given that this information is collected?
a. Need to measure the stream's cross section and the average stream velocity.
Volume flux=cross section of stream x mean stream velocity.
b. To calculate the salmon flux we need to know, in addition to the volume flux, the salmon concentration (number of fish per volume).
Salmon flux=cross section of stream x mean stream velocity x salmon concentration.
If the salmons have a significant velocity in the stream direction replace mean-stream velocity in the formula with mean stream+mean salmon velocity in the along stream direction.

3. In the first class we discussed how the physical aspects of the ocean affect marine organisms. Choose a micro-organism (<0.1mm) and a macro-organism (>1m) and three physical properties of ocean waters. For each physical property describe how it may affect either reproduction or foraging or predation of each organism.

Physical Property	***Effect on copepod***
Temperature	*Affects enzymatic reactions (hence feeding)-digestion speed*
Sound speed	*affects propagation of information on movement near a small organism – hence reaction to a predator/prey*
Light intensity	*Affects visual information – hence ability of predator to prey.*
Physical Property	***Effect on Dolphin***
Temperature	*Affects enzymatic reactions – for example digestion and swimming*

Sound speed *Affects foraging for prey – eco location*
Light intensity *Affects foraging for prey – visual examination*

4. Plot possible temperature profiles for a lake in Maine (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 at the surface is 20°C and the minimal is 0°C (below the ice). Remember that water density is not monotonic with temperature.



Several details I expected you to remember:
1. Coldest (over all) at surface in 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
5. When cooled from above the profile becomes straight.

5. A clam is buried near the sediment water interface pumping approximately 6ml of water each minute and filtering it of its nutritious particles.
a. How many cubic meters of water does it filter in a day?
b. Assuming a concentration of food particles of 30 per cm^3, how many particles does it filter in a day?
c. If each food particle has a nutritional value of 2 Calories, how many Calories does the clam ingests in one minute?
a. 6ml x 60min/hr x 24 hr/day x 0.000001m3/ml = 0.00864 m^3 day^{-1}
b. 30particles cm^{-3} x 1000000 cm^3 m^{-3} x 0.00864 m^3 day^{-1}=259,200 particles day^{-1}
c. 2C particle-1 x 259,200 particles day^{-1} x 1day/(24x60)min = 360C min^{-1}

6. You are asked to relocate a sunken boat to be used as an artificial reef. The boat's weight in air is 200,000N (e.g. mass of ~20,000Kg) and the volume of its solid parts is $8m^3$. Approximately what minimal volume of an air bag should be attached to it so it can be lifted under water to be move to its new location?
Weight in air=200,000N=volume x density x 9.81ms^{-2} →
density = 200,000/8/9.81 = 2548Kg m^{-3}
Weight of boat in water: 200,000 - volume_boat x density_water x 9.81ms^{-2} {=80,050}=119950N
We need a lift bag that displaces enough water to counter this weight (neglecting the weight of bag and air, and assuming a water density of 1020kgm^{-3}):

V_bag x 1020 x 9.81 = 119950N → V_bag=12m^3

7. What is the Re number? What is its dimension? What is it useful for?
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 smaller than one viscous forces dominate while inertial forces dominate when it is larger than one. 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. Water in a tube with a hole at a given height will squirt further on the moon than on the Earth (the gravitational acceleration is less on the moon) F
b. A solid object completely immersed in oil will experience the same upward buoyant force as when it is immersed in water (oil is less dense than water). F
c. The hotter an object the longer the wavelength or the radiation it emits. F
d. Units of pressure in MKS are equivalent to Kg m^{-2} s^{-2} F
e. The density of liquid water is approximately 1Kg m^{-3}. F
f. To determine if an object will float in a fluid we need to know the gravitational acceleration. F
g. Two solid beads of the same material are sinking in a fluid at constant speed. The larger will sink faster. T
h. The no-slip condition implies that a particle next to a stationary wall will sink slower than one in further from that wall. T
i. Light and sound wave increase in speed when propagating from air to water. F
j. 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
k. In the absence of other forces, fluids flow from high to low pressure. T
l. Algae are green because they absorb green light. F
m. Convection refers to passage of heat through contact. F

Multiple choice questions (6pts each):

1. The 'greenhouse' effect:

a. Is mostly due to reflection/emission of visible radiation by the atmospheric greenhouse gases to the Earth's surface.
b. Is mostly due to absorption of visible radiation by the atmosphere greenhouse gases
c. Is mostly due to scattering of infrared radiation by the atmosphere greenhouse gases.
d. Is mostly due to absorption and reflection/emission of infrared radiation by the atmosphere greenhouse gases to the Earth's surface.

2. An object is unstable when:

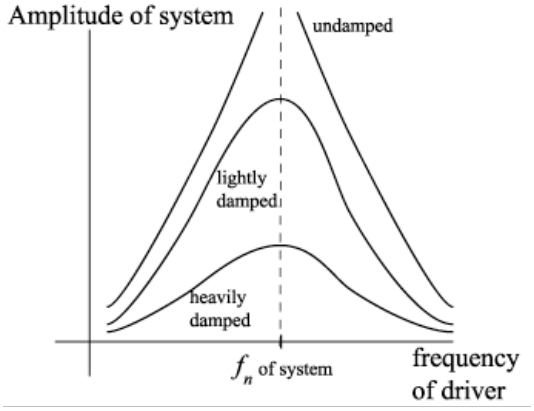
a. Its center of gravity and buoyancy are close.

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.*

3. An object floats in water because:
a. It is lighter than water.
b. Its mass is less than that of water.
c. It has a smaller volume than water.
d. It is less dense than water.

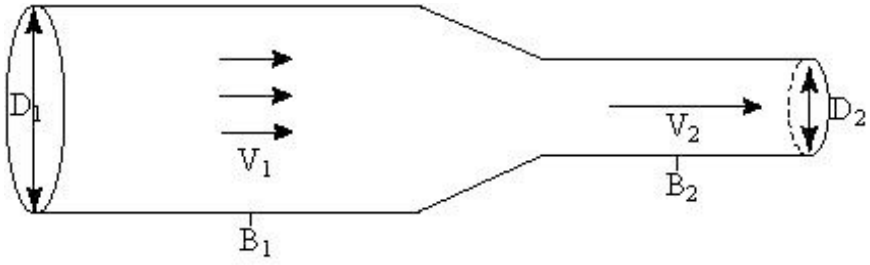
Please provide short answers to the following questions (7pts for questions associated with each picture):

1. What phenomena does this figure represent? How does it relate to the relationship between the size of an organism and the frequency (or wavelength) of sound it emits?



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. In general, the larger the organism (or orchestral instrument) the lower the frequency of sound it emits.

2. What is the principle associated with fluid motion that is illustrated below? How would you expect the pressure to change within this pipe (what other principle did you use to get the pressure distribution)?



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).