SMS-204: Integrative Marine Sciences II (2007).

Mid-term examination (physics part)

Name:

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.

1. An iceberg is floating on the ocean's surface. Its density is 910 kg m^{-3} while the density of the ocean is 1025 kg m^{-3}. How much of the iceberg's volume is above water (in percent)?

The iceberg displaces water equals to its mass: $V_{displaced} \times 1025 \times g = V_{iceberg} \times 910 \times g$
$\rightarrow V_{displaced}/V_{iceberg}=910/1025=0.888.$
$V_{above\ water}=1- V_{displaced}/V_{iceberg}=0.112.$
11.2% of the iceberg is above water.

2. The ocean's volume is approximately 328,000,000 cubic miles. What is the ocean's volume in cubic kilometers (1 mi =1.6093 km)? If the ocean average depth is 3000m, what is its surface area (assume the ocean to be rectangular)?

1 cubic mile = $(1.6093\ km)^3 \sim 4.17\ km^3 \rightarrow 328{,}000{,}000\ cubic\ miles = 1.37 \times 10^9\ km^3$
Surface area = volume/depth= $1.37 \times 10^9\ km^3/3km=4.6 \times 10^8\ km^2$

3. A clam is buried near the sediment water interface pumping approximately 5ml of water each minute and filtering it.
   a. How many cubic meters of water does it filter in a day?
   b. Assuming a concentration of food particles of 10 per ml, how many particles does it filter in a day?
   c. If each food particle has in average 0.01gr Carbon, how many kilograms of carbon does it filter a day?

a. 5ml= $5 \times 10^{-6}\ m^3$***. 1min=1/(60 x 24) =*** 6.94×10^{-4} ***day.***
Total filtered each day: $5 \times 10^{-6}\ m^3 / 6.94 \times 10^{-4}\ day = 0.0072 m^3/day$

b. 10 per ml= 10^7 ***per*** $m^3 \rightarrow$
number filtered per day: 10^7 ***particles per*** $m^3 \times 0.0072 m^3/day = 72{,}000\ particles/day$

c. 0.01g carbon per particles x 72,000 particles/day = 720gr Carbon/day

4. Water flowing out a faucet has a tendency to reduce its cross sectional area. Why?

As the water leaves the faucet it accelerates under gravity. This results in an increase in velocity. By continuity, if it flows faster it has to have a smaller cross-section.

5. Streamlining is a beneficial strategy for certain organisms swimming in water despite the fact that it increases the drag associated with viscous stress in comparison to an organisms with the same volume but with less surface area (e.g. a spherical one). Provide an example of a group of organisms for which streamlining is beneficial? What properties of these organisms have to be taken into account when evaluating whether streamlining is a beneficial strategy for them?

Fish have streamline bodies. We have learned that streamlining is a beneficial strategy at high Reynolds number because it decreases the pressure drag while increasing only slightly the viscous drag resulting in an overall decrease of drag. The properties that need to be taken into account are their velocity and length as these will provide us with their Reynolds number and will allow us to determine whether streamlining is beneficial.

6. Describe the different processes through which a marine organism of your choice gain and loose heat.

All organisms loose heat through black body radiation.
They gain or loose heat to the water around them via conduction through their skin and associated insulating layers.
Movement relative to the water keeps new water next to the skin enhancing heat flux loss/gain. This analogous to convection, e.g. enhanced heat flux due to the movement of the fluid next to the organism.

7. You are at the beach near a 20m deep fresh water lake and have in your hand a balloon with a volume of 1 liter (an analogue of the lungs of a marine mammal). What would be the volume of the balloon if you immersed it all the way to the bottom of the lake assuming no change of temperature (Ideal gas law: PV=nRT, atmospheric pressure~10^5Pa)?

The temperature does not change, so PV within the balloon stays constant.
10m of water represent an increase of pressure of about 10^5Pa (1000kg/m^3 x 9.81m^2/s x 10m~10^5Pa).
At the surface P=10^5Pa, V=1l. At 20m depth P=3 x 10^5Pa (one atmosphere+20m of water). Therefore V(20m)=P(surface)/P(20m) x V(surface)=1/3 l.

True/False questions (2pts each):

a. The density of water is approximately 1kg/liter. T
b. An object whose center of gravity is above its center of buoyancy is unstable. T
c. drag force is always directed opposite the direction of motion T
d. A black object absorbs all visible wavelengths. T
e. Mass flux of water is equals the volume flux of water times density. T
f. Some Microorganisms use jet propulsion as a mechanism to propel themselves. F
g. The no-slip condition implies the existence of boundary layers around objects and near boundaries. T
h. Streamlining reduces viscous drag for high Reynolds number swimmers. F
i. Every object radiates heat according to its temperature. T
j. Total internal reflection can occur when a wave (e.g. light or sound) passes from a fast to slow medium. F
k. To determine if an object will float in a fluid we need to know the gravitational acceleration. F
l. A solid object that floats in warm seawater may sink in cold seawater. F
m. Energy has a dimension of ML^2T^{-2}, in MKS it's units are: Kgm^2s^{-2}. T
n. Convection refers to passage of heat through contact. F
o. At high Reynolds number, viscosity is not a primary contributor to drag . T

Multiple choice questions (6pts each):

1. A Pitot tube is a device used to measure fluid speed by measuring the pressure. Which is the underlying physical principle it is based on?
   a. Archimedes principle.
   b. Bernoulli's principle.
   c. Continuity priciple.
   d. Newton's second law.

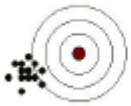
B. You are asked to evaluate whether a water-tight, rectangular container will float or sink in fresh water at room temperature. What measurements do you need to do in order to be able to answer this question?

a. weight of the container;
b. volume of the container;
c. temperature of the container;
d. a and b;
e. a, b, and c.

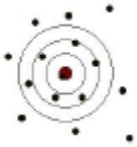
3. To calculate the volume flux of blood in a vein, which are needed?
   a. Mean blood speed.
   b. Cross sectional are of the blood vessel.
   c. Density of blood.
   d. a and b.
   e. a, b and c.

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

1. How is the following illustration related to concepts associated with scientific measurements? What concepts does it illustrate?



Precise but not accurate

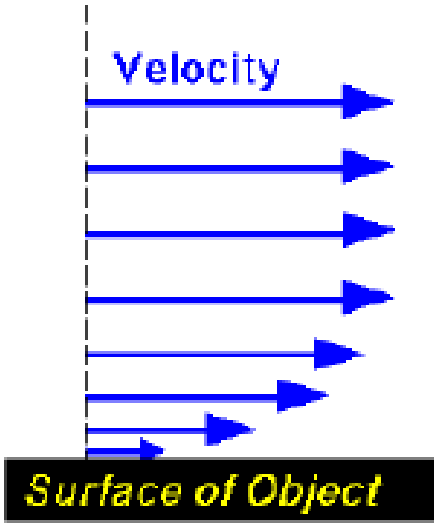


Accurate but not precise

Precise and accurate

The concepts illustrated are precision and accuracy. They are related to scientific measurement because both contribute to uncertainties arising when measurements are done. Precision is often set by the instrument. Accuracy requires that the measuring instrument be calibrated.

2. Explain what phenomenon is illustrated in the figure below. What is the physical principle causing it? What is its most important implication to swimming organisms?



The phenomenon is boundary layer. The physical principle causing it is the 'no slip' condition. The most important implication for a swimming organism is that the no-slip condition cause water to move with the organism resulting in drag, that is the fish needs to spend energy to move fluid with it in additional to itself.