SMS-204: Integrative Marine Sciences II (2011).

Final examination (physics part)

Name:

Please answer all questions (total time 50min): Please provide a <u>short</u> answer to the 6 following questions (7pts each). Please provide your derivations so I can provide you with partial credit in case the answer is not correct.

1. A 2.5m^3 box has a mass of 3000kg. How much will it weigh in water (assume a realistic density for the water, g=9.81 m s^{-2}, and remember that weight is a force)? Approximately what *minimal* volume of an air bag should we attach to it so it floats in water?

Assuming a water density of 1000 kg m^{-3}, the buoyancy force will be equal to 24,525 N (volume of water displaced × density of water × gravity). The weight in water is the difference between the weight in air and that in water = 3000×9.81- 24,525 N=4,905N. Neglecting the weight of the bag and air, we need a lift bag that displaces water with a similar weight, hence Volume of bag × density of water × gravity = 4,905N. → Volume=0.5m^3.

2. A jelly fish sinks at a constant speed while feeding on plankton.
   a. How many cubic meters of water does it filter as function of time 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 jelly fish ingest per minute if the plankton concentration is 1,000 per m^3?
   c. Each plankton provides 0.01 Calories to the jelly fish. How many Calories does the whale ingest each day?

a. Volume filtered per time=speed × area filtered =0.5m^2 × 0.05 m s^{-1}=0.0025m^3 s^{-1}
b. Plankton ingested per time= Volume filtered × plankton concentration = 0.0025m^3 s^{-1} × 1,000 plankton per m^3=2.5s^{-1}=150 plankton min^{-1}.
c. Calories per time = Plankton ingested per time × calories per plankton =150 plankton min^{-1} × 0.01 Calories per plankton = 1.5Cal min^{-1} = 2,160Cal day^{-1}

3. An iceberg is floating on the ocean. Its density is 920 kg m^{-3} while the density of the Ocean's water is 1020 kg m^{-3}. How much of the iceberg's volume is above the water surface (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 × 1020 kg m^{-3} × g

- ➔ *Displaced volume/iceberg volume = 920/1020 = 0.9.*
- ➔ *90% of the volume is under water and 10% of the volume is above the water.*

4. What is the Reynolds number (*Re*) for a swimming organism (write its expression as function of properties of the swimmer and the fluid)? How is the *Re* useful when we analyze the swimming behavior of organisms? Give an example of a low and high *Re* swimmer.

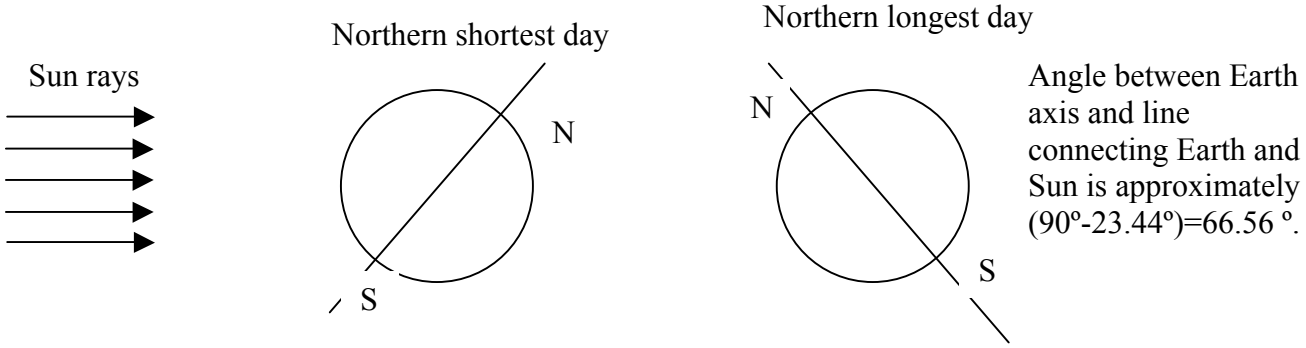
The Reynolds number (Re) for a swimming organism will be:
Re = (organism swimming speed × organism size × water density)/ water viscosity.
Re helps to distinguish between different hydrodynamic regimes. When it is low, viscous forces dominate (e.g. gliding is impossible, and stress drag dominates) while inertial forces dominate when it is large (form (pressure) drag dominate, hence hydrodynamic shape is important). A flagellated phytoplankton is a low Re swimmer while a Tuna fish is a high Re swimmer.

5. Name the three mechanisms for heat transfer. Give one example for each that may be relevant to a marine organism?

Radiation: transfer of heat by photons.
Conduction: transfer of heat through contact.
Convection: transfer of heat through fluid motion.
Radiation warms a sea lion basking in the sun on the Oregon coast as well as cools him through infra red emission.
Conduction cools the sea lion as it swims in the ocean.
Convection causes water close to its skin to move upward replacing it by cold water and thus accelerating the loss of heat.

6. When are the longest and shortest days of the year in Maine? How do they come about (plot a cartoon of the Sun and Earth during these days)? How are they related to the warmest and coldest days of the year and why?

In the Northern hemisphere, the longest June 20th or 21st and shortest Dec. 21st or 22nd. They come about when the Earth axis inclination to the sun is maximal (towards (longest) or away (shortest) from the sun).
The warmest (coldest) day of the years follows AFTER (a few months) the longest (shortest) day of the year. It occurs when the net heating rate is zero (Earth at this location loses the same heat it gains in a 24hr period). Near the longest (shortest) days of the year the net heat gain (loss) is maximal.



True/False questions (2pts each):

a. As water warm in a graduated cylinder the hydrostatic pressure at its bottom decreases. F

b. A swimming organism imparts momentum to the fluid around it. T

c. Radiation is a mechanism to transfer energy without physical contact. T

d. Units of energy in MKS are equivalent to Kg m^2 s^{-2} T

e. A Galileo thermometer works because glass density changes with temperature. F

f. For the same pressure gradient across a hose, turbulence decreases momentum compared to a laminar flow. T

g. Water flows from low to high pressure. F

h. To determine the pressure at a given depth in a fluid we need to know the gravitational acceleration. T

i. A solid object completely immersed in salty water experience less upward buoyant force than when it is immersed in fresh water of the same temperature. F

j. The density of water is approximately 1000g m^{-3}. F

k. Two beads of the same material are sinking in a fluid each at its own terminal speed. The larger of the two will sink faster. T

l. Jet propulsion is a swimming strategy that works for low *Re* swimmers. F

Multiple choice questions (6pts each):

1. The primary reason for the contrast of temperature between the poles and equator is:

   a. Sun radiation spreads over a larger area at the poles.
   b. Poles are further away from the sun than the equator.
   c. Winds and current transport heat from poles to the equator.
   d. Winds and current transport heat from equator to poles.

2. We record uncertainties of all measured physical quantities because:

   a. It gives us a sense of certainty.
   b. It looks professional.
   c. No physical quantity can be obtained exactly.
   d. All of the above.

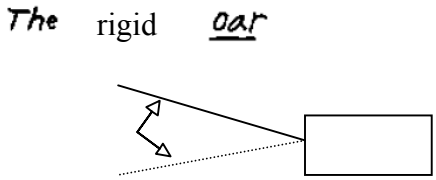
3. An object less dense than the lake water is within a boat floating on a lake. When the object is thrown over the side the water level in the lake will:

   a. Rise.
   b. Stay the same.
   c. Fall.
   d. There is not enough data in the question to answer it.

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

1. Below is a picture of two possible swimming strategies bacteria may adopt. Which is likely to work and why?

The corkscrew works because it is not reversible. At low Re number a symmetric swimming motion (like the rigid oar) will provide no net propulsion (due to the reversibility of the flow).



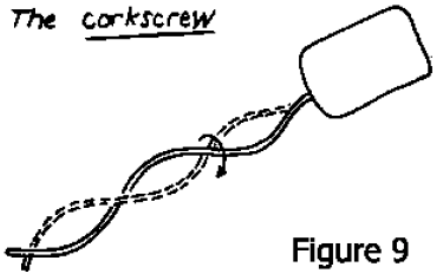


Figure 9

2. What is the principle associated with fluid motion that is illustrated below?

The principle is conservation of energy (here, per unit mass). Potential energy within the fluid is converted to kinetic energy of the fluid exiting the hole. This principle is sometimes called Bernoulli's principle.