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Examination paper for BI-8061, Biological Oceanography

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1. Viscosity. What statement is true?

- A. Viscosity represents friction or resistance against movement of a fluid
- B. Water has higher viscosity than honey
- C. Air has higher viscosity than water
- D. The viscosity of hot water is larger than the viscosity of cold water
- E. The highest known viscosity is that of tar

2. Diffusion. What statement is NOT true?

- A. Molecular diffusion is a small-scale process, which is inefficient compared to the needs of macroscopic organisms for nutrient and gas exchange
- B. Molecular diffusion covers a longer distance in air than in water given the same period of time
- C. Molecular diffusion is modelled on basis of the random-walk model in molecular physics
- D. A fluid with a high molecular diffusion coefficient spreads across a smaller area than one with a low diffusion coefficient given the same period of time
- E. The highest known viscosity is that of glass

3. Reynolds numbers. What statement is NOT true?

- A. Reynolds numbers are dimensionless
- B. Reynolds numbers >2 indicate that turbulent activity is dominating
- C. Flying insects have smaller Reynolds numbers than microscopic flagellates
- D. To overcome viscous forces, some micro-organisms use flagella for fast swimming
- E. Cells are surrounded by a microlayer (film) of water, which is an impediment to nutrient uptake

4. What statement about Reynolds numbers is NOT true?

- A. The speed of swimming has large impact on the Reynolds number of an organism
- B. The larger the organism, the larger the Reynolds number
- C. The more viscous the fluid, the smaller the Reynolds number of the organism
- D. Swimming small copepods live in a viscous environment ($R < 1$), yet when jumping, they enter a turbulent environment ($R > 2$)
- E. Large copepods such as *Calanus* spp. invariably live in a viscous environment

5. What statement about fluids is true?

- A. In gases, viscosity increases with increasing temperature
- B. In a viscous fluid, only turbulent flows can exist
- C. Gases and liquids are collectively known as fluids
- D. Seawater is a non-Newtonian fluid
- E. Honey and tomato ketchup are Newtonian fluids

6. What statement about the sinking rate of plankton is NOT true?

- A. A spherical cell sinks in principle slower the smaller its diameter
- B. Fat or gas vacuoles may help large cells stay in the surface layer
- C. Silicate frustules or calcium carbonate cover may help plankton cells stay buoyant
- D. The density of naked cells typically is close to that of water
- E. Stokes' Law is defined for spherical cells

7. What statement about hydrography is true?

- A. A pycnocline is a relatively sharp increase in salinity with increasing depth
- B. A relatively sharp change in temperature across a narrow depth interval is called a halocline
- C. Typical for the summer season, an oxygen minimum is established near the discontinuity layer
- D. An isopleth graph shows the distribution of hydrographical variables against depth and distance from land
- E. A t-S graph shows the distribution of seawater density against the date

8. What statement about the Coriolis Effect is true?

- A. The Coriolis Effect is caused by the moon's impact on the earth's rotation
- B. The Coriolis Effect is nought (0) at the equator
- C. According to the Ekman spiral, the surface water is deflected 45° to the left relative to the wind direction at 60-70° northern latitude
- D. The Coriolis Effect is largest for bodies that do not move
- E. Wind surrounding a low pressure (depression) at northern latitude forms a clockwise spiral

9. What statement about wind systems is NOT true?

- A. The northernmost and southernmost jet streams encircle Arctic and Antarctic bodies of cold air, respectively
- B. The trade winds (easterlies) cause, by inducing upwelling, phytoplankton blooms along the west coasts of South America and West Africa, and along the equatorial zone
- C. Upwelling marine ecosystems are the most highly productive of the sea
- D. Upwelling systems are characterised by relatively warm surface water, which favours anchovies to sardines
- E. Both the Subarctic seas and the Southern Ocean lie in the west-wind belts

10. Which statement about the Coriolis Effect is NOT true?

- A. The deflection is to the left in the Southern Hemisphere
- B. Depressions/storms, irrespective of which hemisphere, are called cyclones
- C. The Coriolis Effect increases with increasing latitude
- D. The Coriolis Effect is strongest at the equator
- E. The Coriolis Effect is too small to be measurable in small-scale systems such as a pond

11. Which statement about the Coriolis Effect is NOT true?

- A. A high Rossby number indicates that a system is too small to be affected by the Coriolis Effect (example, a thunderstorm)
- B. Only in thin-layered currents the Coriolis Effect may have an impact in systems as small as a fjord
- C. Kelvin waves exist only in deep mid-ocean basins
- D. The waves of the jet streams are known as Rossby waves
- E. Ocean-spanning whirls are known as gyres; smaller whirls are known as eddies

12. Thermohaline circulation (THC). What statement is NOT true?

- A. THC is a global system of horizontal and vertical currents
- B. Globally, wind is the main driving agent of THC
- C. Bottom water is mixed with other waters because of tidal waves causing mixing in undersea mountain ranges
- D. Greenland and Labrador Seas do not produce bottom water because of high temperature
- E. There is no production of bottom water in the Pacific Ocean

13. Why does not any part of the Indian Ocean produce bottom water? What statement is true?

- A. The surface water is too warm, causing too small surface density
- B. The question is misleading because the Indian Ocean does produce bottom water
- C. Production of sea ice in the Southern Ocean is a hindrance
- D. The surface salinity is too low, causing too small density
- E. The tidal forces are not strong enough

14. What kind of wind, according to the Ekman spiral, is most likely to cause upwelling along the west coast of Norway? Which statement is true?

- A. From North/Northeast
- B. From South/Southwest
- C. The wind direction is not of consequence
- D. Wind from the North followed by southerly wind after a few days
- E. No wind

15. What statement about ENSO is true?

- A. El Niño is most likely when the Southern Oscillation (SO) index is negative
- B. El Niño arises when the trade winds are abnormally strong
- C. The SO index is the normalised difference in atmospheric surface pressure between Darwin (Australia) and Tahiti
- D. La Niña causes droughts in Australia and Southeast Asia
- E. El Niño causes particularly high primary production in the coastal waters off Peru

16. What statement about the NAO index is true?

- A. A positive index implies a narrow and fast Atlantic Current
- B. A positive index implies large bottom water production in the Greenland Sea
- C. A positive index implies large production of sea ice along the Siberian shelf
- D. The NAO index was strongly positive in the 1960s
- E. A negative index implies enhanced biological production in the Barents Sea

17. What statement about marine primary production is NOT true?

- A: It is large in upwelling areas because nutrient-rich deep water is lifted to the surface
- B: It is relatively small on the Alaskan Shelf because of small upwelling at the shelf edge
- C: It is large in the deep Arctic Ocean because sea ice protects against UV radiation
- D: It is small in the Sargasso Sea because of a strong thermocline that hinders upwelling
- E: It can be smaller in a Norwegian fjord than offshore because of the much higher turbidity of fjord water

18. What statement about the processes of the planktonic food web is NOT true?

- A. Growth and loss of plankton biomass are essentially exponential
- B. The supply of resources needed for growth in food webs is known as a bottom-up control
- C. The main resources required for phytoplankton growth is nutrients, CO₂ and light
- D. Physical forcing is important for life and growth of plankton
- E. Phytoplankton biomass is mainly lost through dilution, mixing and advection.

19. What statement on food web components is NOT true?

- A. Heterotrophic flagellates (HNF) are known as small nanoplankton.
- B. Large krill species feed mainly on copepods.
- C. Meroplankton are represented by many species and constitute a highly diverse group
- D. Appendicularia are relatively large organisms, yet they feed mainly on small nanoplankton.
- E. Bacteria are often called heterotrophic picoplankton.

20. Among the species of inorganic carbon, which one is the most abundant in seawater?

- A: Free CO₂
- B. Carbonate ions
- C. Calcium carbonate
- D. Bicarbonate ions
- E. Carbonic acid

21. What statement about biological calcification is true?

- A. There will be more of free CO₂
- B. There will be more of nitrate
- C. Alkalinity will increase
- D. There will be less phosphate
- E. pH will decrease

22. Why are the Nordic Seas and the Southern Ocean efficient CO₂ sinks? Which statement is true?

- A. Because bottom water is produced there
- B. Because there is less light than in the tropical zone
- C. Because the calcium carbonate concentration is higher there
- D. Because the nitrate concentration is higher than in the tropical zone
- E. Because a freshwater layer is established at the surface in summer

23. What statement about the carbon cycle is NOT true?

- A. The global ocean sequesters between 1.5 and 2.5 petagrammes of carbon annually
- B. Biological carbon pumping is possible because cold water can hold more CO₂ than warm water
- C. Export production is the amount of organic material that sinks out of the surface layer
- D. Calcium carbonate is more soluble in warm than in cold water
- E. The biological pump is closely coupled to the primary production in the sea

24. Dissolved iron exists in the sea as the following species (from least to most). What statement is true?

- A. Organic complexes and colloids < free Fe(II) and Fe(III) ions < inorganic complexes
- B. Free Fe(II) and Fe(III) ions < organic complexes and colloids < inorganic complexes
- C. Inorganic complexes < organic complexes and colloids < free Fe(II) and Fe(III) ions
- D. Organic complexes and colloids < inorganic complexes free < Fe(II) and Fe(III) ions
- E. free Fe(II) and Fe(III) ions < inorganic complex < organic complexes and colloids

25. Judged by their roles in biology, how can we classify Fe, Zn, Cu, Cd and Ni? What statement is true?

- A. As micronutrients
- B. As conservative metals
- C. As reactive metals in so-called «scavenged» particles
- D. As heavy metals
- E. None of the above

26. Which one metal plays a critical role for nitrogen assimilation (N_2 fixation and reduction/uptake of NO_3^- and NO_2^-) and nitrogen dissimilation (denitrification, NH_4^+ oxidation)?

- A. Mo
- B. Zn
- C. Fe
- D. Cu
- E. Mn

27. The attenuation coefficient for light in seawater is a function of: ... What statement is true?

- A. Phytoplankton (pigment) concentration
- B. Water, phytoplankton pigment concentration, other particles (silt and detritus included) and dissolved coloured organic matter (cDOM)
- C. Water, temperature, silt and detritus, and dissolved coloured organic matter (cDOM)
- D. Water, temperature, salinity, pigment concentration, silt and detritus, and dissolved coloured organic matter (DOM)
- E. Pigment concentration, silt and detritus, and coloured dissolved organic matter (cDOM)

28. What statement about light is true?

- A. The sky appears blue because the atmosphere absorbs red light
- B. In the clearest seawater, violet light penetrates deepest
- C. cDOM gives coastal waters off Norway its green hue
- D. Oceanic seawater appears blue mainly because of Rayleigh scattering
- E. Irradiance is radiation hitting a surface from a specified angle

29. What statement about light is NOT true?

- A. Colour is imagined by the brain and is a function of energy per photon (or wavelength)
- B. Maximum reflection from a calm sea surface occurs at noon
- C. Clouds produce mainly spectrally neutral and forward Mie scattering
- D. The colour of *Emiliana huxleyi* blooms reflects mainly the colour of the above-lying water
- E. Calcium carbonate in coccoliths causes strong reflection back to the surface

30. Why is ocean colour measured in the visual spectrum (400-700 nm)?

- A. Detectors exist only for this wavelength band
- B. Most of the matter that contributes to ocean colour absorbs in the 400-700 nm band
- C. It is the only wavelength band that can be seen by the human eye
- D. Because only the 400-700 nm wavelengths are sufficiently energetic for detection by satellite sensors
- E. To separate between night and day

31. What statement is true?

- A. The Atlantic Current in the Norwegian Sea is dominated by Gulf Stream Water
- B. Estuarine circulation is a combination of an inflowing surface current with an outflowing bottom current
- C. Through the Straits of Gibraltar, the surface current flows into the North Atlantic and the bottom current into the Mediterranean Sea
- D. Most of the ocean water that flows into the central Arctic Ocean is of Pacific origin
- E. Two bodies of water, one on top, the other underneath, are called metastable if their density is the same yet temperature and salinity are different.

32. What statement is NOT true?

- A. A geostrophic current is a current in which friction and the Coriolis force are exactly balanced
- B. Thermal expansion is the reason that the sea level may be up to 1 metre higher in the tropics than in the Polar seas
- C. The Gulf Stream and the Kuroshio are examples of western boundary currents
- D. Western boundary currents are known to be wide and slow
- E. There is no parallel to the North Atlantic Current in the Pacific Ocean

33. What statement is true?

- A. The water that surrounds the large, central oceanic gyres circulates clockwise in the Northern Hemisphere and anti-clockwise in the Southern Hemisphere
- B. Air masses that flow from high to low pressure are not affected by the Coriolis Effect
- C. The Coriolis Effect is stronger near land than in the mid ocean
- D. The Coriolis Effect is caused by the tidal forces created by the sun and the moon
- E. The Coriolis Effect is clearly evident in fountains situated a couple of hundred metres from the equator

34. Which region is most vulnerable to iron limitation?

- A. The Indian and South Atlantic oceans
- B. The Southern Ocean
- C. The Indian Ocean and the Mediterranean Sea
- D. The North Atlantic and the tropical part of the Pacific
- E. The Arctic Ocean

35. Photosynthesis and respiration. What statement is correct?

- A. Photosynthetic organisms have no need to do respiration
- B. Photosynthesis and respiration are two completely unrelated processes
- C. Respiratory losses are defined as the rate of electron flow from organic carbon to CO₂
- D. When calculating net photosynthesis and net primary production, we separate between respiration done in the light, R_L and respiration done in the dark, R_D
- E. Net photosynthesis, P_N is the difference between gross photosynthesis and respiration losses both in the light and in the dark

36. Production. What statement is NOT correct?

- A. Gross primary production is equivalent to gross photosynthesis
- B. Net primary production (NPP) is defined as all organic carbon produced by photosynthesis within an ecologically relevant time period and which is available to other trophic levels
- C. Net primary production is often given as daily or annual net primary production
- D. Net primary production is the difference between the net photosynthetic rate and the dark respiration rate
- E. Net primary production is the same as net photosynthesis

37. Production. What statement is NOT correct?

- A. About half of the estimated global primary production takes place in the oceans
- B. The main primary producers in the world ocean are macro-algae (kelp and seaweeds)
- C. Macro-algae are important primary producers in coastal areas, and also important as keystone species of kelp forest habitats by offering food, shelter, substrate, etc., for other species
- D. Phytoplankton can form large blooms that support other species at higher trophic levels
- E. Primary production takes place even in the more extreme environments in the ocean, e.g. by ice algae underneath the ice cover in Arctic and Antarctic seas

38. Phytoplankton functional types (PFTs). What statement is correct?

- A. The 7 major PFTs are defined according to their biogeochemical role, light sensitivity, behaviour, and qualitative importance in specific geographical regions
- B. The 7 major PFTs are based on primary production characteristics, light sensitivity, behaviour, and qualitative importance in specific geographical regions
- C. The 7 major PFTs are based on their biogeochemical role, physiological and environmental requirements, behaviour, and qualitative importance in specific geographical regions
- D. The 7 major PFTs are based on their primary production characteristics, acclimation status, biomass, and harmful algae
- E. The 7 major PFTs are based on their biogeochemical role, acclimation status, harmful algal blooms, and qualitative importance in specific regions

39. Remote sensing of phytoplankton blooms. What statement is correct?

Polar orbiting satellites with multispectral imagers offer an excellent method to cover:

- A. Selected areas, produce time-series, detect seafloor habitats, and create maps that are easy to understand by the end user.
- B. Large areas, make time-series, operational data (for management & decision making), create maps that is easy understandable for end user.
- C. Large areas, map fish stocks, operational data (for management & decision making), create maps that is easy understandable for end user.
- D. Large areas, look at physiological responses in phytoplankton, operational data (for management & decision making), create maps for experts only
- E. Selected areas, make geo stationary time-series, operational data (for management & decision making), create maps that are easy to understand for end user.

40. Key environmental variables that directly affect marine zooplankton behaviour and reproduction in the water column. What statement is correct?

- A. Nitrate concentration, prey (food availability), temperature, oxygen concentration in the water, pressure, salinity, current speed and direction.
- B. Light, prey (food availability), predators, temperature, oxygen concentration in the water, salinity, current speed and direction.
- C. Light, temperature, pressure, salinity, wave action.
- D. Light, prey, freshwater run-off, coloured dissolved organic matter (cDOM), current speed and direction.
- E. Light, prey, alkalinity, trace amounts of iron, oxygen concentration in the water, pressure, salinity, current speed and direction.

41. What limits marine biological observations during the polar night? What statement is NOT true?

- A: High economic expenses, darkness, wave action, ice cover and ice thickness.
- B: Range limitations of research vessels, too little sea ice, dark and cold
- C: Few ice-going vessels, limited use of sensor platforms such as underwater robots
- D: Cold and dark, high human health risks, few available ice-going vessels
- E: Cold and dark, ice cover, logistical constraints, satellites that cannot “sense” biological features in the dark