EOSC 112 - CHAPTER 5 SOLUTIONS

REVIEW QUESTIONS:

1. What effects does the surface-wind pattern have on the circulation of the oceans?

The movement of the wind over the ocean causes friction at the surface. As a result of this friction, the wind drags the ocean surface with it as it blows, thus setting up a pattern of surface-ocean wind-drift currents.

2. Why do ocean currents not move in exactly the same direction as the wind?

Because of the Coriolis Effect, ocean currents do not move in exactly the same direction as the wind. The Coriolis Effect influences ocean currents just as it does winds, so the water is deflected to the right of the path of the wind in the Northern Hemisphere (and to the left of the wind's path in the Southern Hemisphere). Observations show that this deflection tends to be approximately 20–25° from the wind direction.

3. What is the Ekman spiral? Explain why Ekman transport occurs.

Due to friction between wind and the water surface, some of the kinetic energy of the air is transferred to the top layer of the water. As that layer moves, it drags along the water just below it, which in turn drags along the water just below that, and so on. The water can be thought to move as many thin, coupled layers, and kinetic energy is transferred down the water column. However, as the energy is transferred downward, friction causes some of the energy to be dissipated in the form of heat, so each level moves more slowly than the level above. At some depth below the surface, the effects of the wind-induced movement disappear. However, as each layer moves, it is again subject to the Coriolis Effect. Once a layer starts to move, the water is deflected to the right of the path of the layer above (or the wind path, for the surface layer). This movement is to the right in the Northern Hemisphere and to the left in the Southern Hemisphere. The deeper below the surface, the farther each layer is deflected to the right or left of the surface layer, producing a spiraling effect known as the **Ekman spiral**. When the movements of all the individual layers of water in the spiral are added, the net direction of transport within the water column is at a right angle (90°) to the wind direction. This net movement of water is referred to as **Ekman transport.**

4. What is upwelling? Where does upwelling occur?

Where divergence occurs at the surface, water must rise from below to replace it. Water at depth is cooler than water at the surface. The rising of cooler water to the surface to replace warm, divergent surface water is referred to as **upwelling.**

5. What is meant by a geostrophic current?

There is a force due to gravity, acting down the gradient of the surface slope that is opposed by the Coriolis Effect. The net effect is a flow of water at approximately 90^o to the slope. The result is a geostrophic current that flows approximately perpendicular to the slope of the sea surface around the gyre.

7. **Where does the salt in the oceans originate? Are the oceans getting saltier and saltier with time? If not, then why not?**

The salts contained in seawater are largely the result of the weathering of crustal rocks. The oceans are not getting saltier, because many processes also remove salts from seawater. These processes include the following:

i. Evaporation of seawater from shallow seas. The remaining salts are concentrated and precipitate from solution as **evaporite deposits**, such as halite (table salt, NaCl) and gypsum ($CaSO_4 \cdot 2H_2O$).
ii. Biological processes. For example, some marine organisms remove the elements calcium or silicon from seawater to form their shells, some of which are eventually deposited in ocean sediments.
iii. Chemical reactions between seawater and newly formed volcanic rocks on the sea floor.
iv. The formation of sea spray. As small droplets of seawater become airborne, salts, especially sodium and chlorine, are removed when the spray is deposited on land. These salts are eventually returned to the oceans via rivers.

Overall, salts are removed from seawater at a rate that essentially equals the rate of input, when averaged over geologic time scales (millions of years).

8. **Define the thermohaline circulation. What are the processes that drive the circulation of the deep oceans?**

Because deep-ocean circulation depends on temperature and salinity, this circulation is referred to as **thermohaline circulation** (*thermo* is Greek for "heat," and *haline* comes from the Greek *hals*, for "salt"). In the deep oceans, horizontal changes in density are small, whereas vertical changes can be larger. But the densest water is at the bottom, so the structure is very stable. Consequently, the movement of water through the deep ocean is relatively slow.

9. **Explain the differences among the pycnocline, the halocline, and the thermocline.**

The transition zone between the surface zone and the deep ocean is on the order of a kilometer in thickness and is characterized by a rapid increase in density with increasing water depth. The very sharp increase in density is called the **pycnocline**; the transition zone is referred to as the *pycnocline zone*. In some regions this density gradient is dominated by salinity changes, and salinity rises rapidly with increasing depth. In this case, the salinity gradient is specifically referred to as the **halocline**. In most other regions, temperature changes dominate the density gradient, and temperature drops rapidly with increasing depth. There the transition is called the **thermocline**. In any of these cases, a steep density gradient forms that makes this stratification very stable.

10. **What is bottom water? Where and how does bottom water form?**

Bottom water constitutes the densest water produced in the oceans. Near the poles, the surface waters are cooled below the normal freezing point (-1.9°C in some areas) by contact with the cold overlying atmosphere. (The freezing point is lower than that of pure water because of the presence of salt.) When that water freezes, it forms a layer of sea ice several meters thick that floats on the surface of the polar oceans. When the ocean surface freezes, most of the sea salt is excluded, because the salt does not fit into the crystal structure of the ice. As a result, the water just beneath the sea ice becomes saltier, and an underlayer of very cold, highly saline water forms. The combination of low temperatures and high salinities results in very dense water that sinks and flows down the slope of the basin and spreads toward the equator as the bottom layer of water in the deep-ocean basins.

11. What is meant by the term *thermohaline conveyor belt*?

The thermohaline conveyor belt is the process by which deep water is transported around the globe. Deep water first forms in the North Atlantic, where downwelling of cold waters with relatively low densities occurs. After downwelling, this deep water moves south to the Antarctic, then to the Indian and Pacific Oceans, and finally to the North Pacific where it resurfaces. The downwelling in the North Atlantic is balanced by surface flows that bring water to the North Atlantic.

The thermohaline conveyor belt is a significant feature of the Earth system in several respects: It plays a dominant role in the recycling of ocean nutrients, and it has a major impact on Earth's climate. Much of the life that exists in the oceans can be found in the near-surface layers, using sunlight for photosynthesis—phytoplankton, for example—or living off the animals that feed on phytoplankton. These plants and animals use the nutrients in ocean water, so the surface layers become relatively depleted in nutrients. When these organisms die, they sink through the water column, decompose, and release the nutrients back into the water. The deeper ocean, therefore, is relatively rich in nutrients. The thermohaline circulation transports these nutrient-rich waters around the globe, returning the nutrients to the surface in areas of upwelling, primarily along the continental margins.

12. Explain what effects the ocean has on modifying the global temperature distribution.

The ocean circulation has a strong influence on global temperatures. The transport of warm surface water toward the poles, to replace the bottom water that forms near the sea-ice margin, is one mechanism by which excess solar energy is transferred poleward. The oceans represent a vast reservoir of heat, absorbing heat from the atmosphere in some areas and releasing it in others. Because water heats up and cools down relatively slowly, pools of water that are cooler than normal or warmer than normal will cool or warm the atmosphere on time periods of months to seasons or years—the time needed for the pools of water to heat up or cool down. On much longer time periods, however, the average effect of the oceans on the atmosphere is determined by the overall temperature of the oceans. Most of the water in the oceans lies in the deep oceans, and its temperature is largely determined by the process of bottom-water formation and by the transport of bottom water around the ocean basins. If the process of bottomwater formation changes, the ocean temperatures will change—and so will climate.