Exploring the World of Science

University of Michigan Science Olympiad
2021 Invitational Tournament

Dynamic Planet C

Test length: 50 Minutes

Team name: KEY

Student names: KEY

Intro Page [242 points]

Things you should probably know:

1) We don't need complete sentences. As long as you get the point across, that's good enough for us. Lists ARE an acceptable explanation format. That bein sad, f u make noo cents and write like a crackhead, we won't waste time grading it.
2) There are 7 tiebreakers. We will go 1-7 in breaking ties.
    a) If they say "Tiebreaker X with points", that means the question is part of your exam score and will also be used to break ties. You'll notice that much of the higher tiebreakers are with points. That's because they're awesome questions.
    b) If they say "Tiebreaker X (0 points)" We will only use these questions for tiebreakers, so we would recommend doing these only if you have time.
3) We put some mad jokes in the test. Please fake laugh for us.
4) The test is split up into sections we find in the rules. Do with this information what you will.
5) If you can't see the images, there is an image sheet separate from the test.
6) Your two test writers are: Manish Venumuddula(manishrv@umich.edu) & Siri Vangavolu(vangavolus@gmail.com). If you have any questions about the test, spot any wrongdoings, or really, just wanna jam about anything, reach out to us. We love hearing from you guys! If you just wanna say hi, please do.

I. Seawater: composition, density, variations in salinity, and sources of salts [20 possible points]

1. We all know the six major ions present in the oceans, but what are 2 major salts? (1 point)

NaCl, MgCl2, KCl, MgSO4, K2SO4

2. What are the two major processes that affect salinity? (1 point)

Evaporation & Precipitation

3. What is the most common source of the salts in the ocean? (1 point)
    a) Rivers
    b) Hydrothermal Fluids
    c) Rocks on Land
    d) Sneezes

4. Why is the Atlantic Ocean saltier than the Pacific Ocean? [Supervisor Recommendation: List as many possible answers as you can] [TieBreaker 3] (1 point/correct answer. Out of a possible 5)

Supervisor Note: Any of the following work, if more than one are given, add points as necessary*

a. Vapor Transport from the Atlantic to the Pacific (across the Isthmus of Panama)
b. Agulhas Leakage
c. Input of High Salinity water from MOW(Mediterranean Outflow Water)
d. Excess evaporation in Atlantic SubTropical Gyres
e. Possible because the Atlantic is Smaller **If seen, ask supervisor

5. What is the principle that states that the proportions of major salts stay the same relative to each other? (2 points)

Forchhammer's Principle

6. What is the freezing point of a sample of seawater, given a water freezing constant of 1.86 ℃/m and a salt molarity of 1.07527?

Freezing Point Depression = Freezing Constant * Molal.
Substitute Given: Answer: -2 ℃
(4 Total Points)
+1 - Formula
+2 - Answer & Proper Substitution
+1 - Units & Overall Cleanliness (Can't get these points without answer points)

7. We are always told that temperature and salinity affect density, but by how much? Calculate the ΔDensity or seawater given the following:

a. The thermal expansion coefficient: ~0.2 $\frac{kgm^3}{C}$

b. Saline contraction coefficient: $1\frac{kgm^3}{psu}$

c. ΔT= 15 ℃

d. Salinity changes from 35 ppt to 38 ppt.

1) Recognize ppt ~ psu
2) Formula: ΔDensity = α*ΔT+β*ΔS
3) Answer: 6 kg/m^3

(+6 points)
+1 - Recognizing ppt ~ psu
+2 - Formula
+2 - Answer
+1 - Units & Overall Cleanliness(Can't get these points without answer points)

II. Shortwave and longwave radiation, sensible and latent heat fluxes, geothermal heat, and heat transport [14 points]

1. The Earth emits which kind of radiation? (1 point)
    a) Shortwave
    b) Longwave
    c) Mie scattering radiation
    d) Sodium pentafluoride waves

2. What is a greenhouse gas? [Supervisor Recommendation: Don't spend too much time on this! A quick and dirty explanation is all we need] (2 points, +1/step)

Supervisor Note: Some Variation of the following two steps. Low Points for Googlability

1) Some statement of greenhouse effect: "Keep Earth warm like greenhouse"
2) A GHG absorbs & reemits LW Radiation while allowing SW radiation to pass through. (If student says GHG's 'reflect heat', no points should be given)

3. What's the standard letter to represent heat in a mathematical or chemical context? (1 point)
    a) H
    b) S
    c) U
    d) R

4. What is the main source of geothermal heat in the Earth? (1 point)
    a) The Sun
    b) Residual Heat from the Earth's formation
    c) Radioactive Decay in the Mantle
    d) Overeager squirrels in the core

5. Originally, scientists believed basal drag was the primary driving mechanism behind plate movement. However, more recently, scientists believe there is a different driving mechanism behind plate movement. What two processes does this driving mechanism contain? (3 points, No Partial Credit)

Slab Pull and Ridge Push

6. What is the difference between sensible heat and latent heat? [Supervisor Recommendation: Don't spend too much time on this! A quick and dirty explanation is all we need] (2 point, +1/definition)

Some variation of the following: Sensible heat is the heat lost or gained that changes the temperature of the body, while latent heat is the heat lost or gained changing phases of matter of a body.

7. Ocean Thermal Energy Conversion is a proposed form of electricity generation that uses the thermal gradient of the ocean to….generate electricity.
    a. If I start with a cubic meter of water at the surface of the ocean at approximately 25℃ and leave it at 0 ℃, how much energy is released? Assume: Specific Heat of 3.850 J/(g℃), Density of 1.0273 g/cm$^{3.}$ We don't care about Sig Figs and answer in MegaJoules to 2 decimal places. (4 point)

1) Formula of Q = mcΔT. Recognize Density of Seawater
2) Substitute
3) Answer: 98.88MJ

+1 - Formula
+2 - Answer in MJ
+1 - Units & General Cleanliness(No points w/o answer points)

    b. What is the theoretical maximum amount of energy we can capture from this? Hint: Carnot's are my favorite vegetable. [TieBreaker 7] (0 points)

1) Carnot Efficiency: 1- T_{Cold}/T_{Hot} = 8.39%
2) Theoretical Maximum = Carnot * 98.88MJ = 8.30 MJ

TieBreaker Points:
+3 - Carnot Formula
+1 - Solving Correctly.
+1 - Calculating Theoretical Maximum with Carnot Efficiency
+1 - Answer in MJ
+2 - Units & General Cleanliness(No points w/o correct answer)

III. Water temperature, pressure, and the three-layer structure of ocean water (20 points)

1. Describe the relationship between temperature and salinity of ocean water. (1 point)
   As temperature decreases, salinity increases.
2. Which latitudes have the highest surface salinities? Why? (2 points)
   30-40 degrees north and south of the equator, because these areas experience the highest differences between evaporation and precipitation rates.
3. Match the thermocline to the halocline at the same latitude. (1 point)
   (See image sheet) Thermocline A - Halocline A, Thermocline B - Halocline C, Thermocline C - Halocline B
4. What are the three layers of the ocean? How are they divided? (2 points)
   Surface, mixed, and deep layer; divided by water density (0.5 for salinity or temperature)
5. Describe the relationship between salinity content of water and its freezing point. Which layer of the ocean would be the hardest to freeze based on salinity content alone? (4 points)
   Higher salinity content means lower freezing point, so the surface would be harder to freeze
6. Given the pycnoclines at each latitude, describe how a sound wave would travel from the top layer to the bottom, assuming the sound wave does not dissipate. (6 points - 3 points for each correct description)
   In low-latitude pycnocline, a sound wave would move slowest through the surface/mixed layer due to the low density of the water. The sound wave would move at a higher velocity as it propagated deeper into the ocean, as the water gets denser.
   In the high-latitude pycnocline, a sound wave would move at the same high velocity through the layers of the ocean, since they are all of (relatively) uniform density.
7. Why are the layers of the ocean stratified? How long does it take for a water particle from the bottom layer to move to the middle layer? What about from the middle layer to the surface layer? (3 points)
   Denser water sinks and less dense water “floats” on the surface. This creates layers of denser water as you move deeper into the ocean. 1000 years for both
8. Name the four types of oceanic sediments and describe their origins. (4 points)
   Lithogenous - sediments from land that enter ocean via erosion; Biogenous - from shells of plankton, diatoms, etc.; Hydrogenous - sediments formed by chemical reactions in water; Cosmogenous - sediments from atmosphere or space (meteorites)

IV. Topographic features found at continental margins, estuaries, ocean basins, and mid-ocean ridges (19 points)

1. What are four types of estuaries based on origin? Describe the key topographic features of each. (8 points - 1 point for each estuary, 1 point for each description)
   Drowned river valleys/coastal plain estuaries - wedge shaped in cross section; Lagoon/bar-built estuaries - isolated from ocean by barrier islands/spits or beaches; Fjord - steep sides, rock bottoms, and underwater sills contoured by glacial movement, is shallowest at its mouth; tectonic - formed by subsidence or land cut off from the ocean by land movement associated with tectonic activity
2. Describe the two types of continental margins and give two real-life examples of each. (4 points - 2 points for name & description, 1 points per example)
   Passive - far from a tectonic boundary and have little to no major tectonic activity (examples include east coast of U.S., west coast of Africa, Gulf of Mexico area, Australia's coasts, west coast of Europe);
   Active - near on on a tectonic boundary, have some major tectonic activity (examples include west coasts of U.S. and South America, northeast/east coast of Africa, east coast of Asia/Japan, Mediterranean Sea area)
3. How are submarine canyons formed? (2 points)
   a) Turbidites
   b) Displacement/cleaving by plate movements near the continental slope
   c) Erosion by turbidity currents
   d) They were clawed into the Earth by an evil space monster

   Formed by continuous erosion by turbidity currents that run down the continental slope
4. What two general terms describe the silica content of magma? How do these two types differ in viscosity? Give an example of a rock of each type. (3 points - 0.5 for each of the two types & following questions)
   Felsic & mafic; Felsic is more viscous than mafic; Felsic - granite, rhyolite, tuff, pumice, obsidian; Mafic - basalt, diabase, gabbro, scoria, dolerite
5. Describe the difference between seamounts and guyots. (2 points)
   a) Seamounts are underwater, guyots are above ground
   b) Seamounts have a peak, guyots are flat-topped
   c) Seamounts are nonvolcanic, guyots are volcanic
   d) The person asking this question is dumb, there's obviously no difference

V. Processes and features of tectonic plate motion in ocean basins and patterns of age of the ocean floor (17 points)

1. Describe the process of seafloor spreading. (2 points)
   Magma is pushed up through a mid-ocean ridge/rift valley, wedges the surrounding tectonic plates apart. The magma cools and solidifies, forming new seafloor on either plate.
2. Who proposed the currently accepted theory of seafloor spreading? What was the previous theory, and who developed it? (3 points)
   Harry Hammond Hess; Alfred Wegener provided the previous theory which was that the seafloor was immovable
3. Why are geomagnetic reversals important in relation to seafloor spreading? (2 points)
   The effect of geomagnetic reversals (paleomagnetic stripes) are used to measure the rate of seafloor spreading.
4. Near what type of margin would the oldest seafloor on Earth be found, and why? (2 points)
   Passive margin, because an active margin would eventually destroy or consume all seafloor near it
5. What is the Wilson Cycle? List and describe its stages. (3 points)
   The cycle of tectonic formation and destruction of ocean basins.
   Embryonic - a rift valley forms in a continental land mass
   Juvenile - the rift widens and allows a shallow sea to form
   Mature - continued divergence and deepening of the ocean
   Declining - convergent boundaries begin to form at the edges of the ocean basin and subduction begins
   Terminal - subduction makes the ocean basin progressively smaller and the ocean gets shallower again
   Suturing - continents/coasts on either side of ocean connect and suture together (mountain belt forms)
6. What is an aulacogen? How does one form? [Supervisor recommendation: Be specific when answering the second question.] (3 points - 1 point for definition, 2 points for formation)
   The failed arm of a triple junction in a tectonic rift system. Forms because two arms of the rift diverge and create basins while the third arm becomes dormant due to sediment accumulation.
7. Scientists are tracking the movement of two correlated paleomagnetic stripes on the seafloor. The stripes are 140m from each other. How long ago were the created if the spreading rate of that rift is 3cm per year? Show your work. (2 points - 1 point for work, 1 point for answer)
   [Supervisor note: Students need to remember to divide distance in half.] 70m/(3cm/yr) = 233.33 years

VI. Distribution of chemicals (e.g., nutrients, oxygen, metals) in the ocean, as well as vertical and horizontal structure [18 points]

1. What are two ways chemicals and elements can be distributed in the ocean(Vertically or Horizontally)? (4 points, +2/way)

Supervisor Note: Difficult Question

1) Plankton and other life form dying. Transporting nutrients vertically downward.
2) Ocean Currents
3) Sources & Sinks of certain elements determine concentrations in certain places.

2. Conservative elements:
    a. What is a conservative element? (1 point)

Elements that are distributed evenly vertically and horizontally

    b. What is the only process that can cause changes in concentration of these types of elements? (2 points)

Removal/Addition of Water through Evaporation or Precipitation

3. Nutrient-Like elements are elements that are depleted at the ocean's surface due to biological processes(absorption/uptake from plankton). Do nutrient-like elements have longer or shorter residence time than conservative elements? Why? (4 points, +1 for answering shorter & +3 for explanation)

1) Shorter
2) B/C Sometimes the nutrients end up in the sediment at the bottom of the ocean(Removed from the Ocean) instead of getting cycled in MOC

4. Scavenged elements are those that react with other particles and are absorbed into them. Because of this, they generally have fairly short residence times. From that information or previous knowledge you have acquired, what would the general depth profile of a scavenged element look like? (2 points)
    a) Increase with Depth
    b) Decrease with Depth
    c) Doesn't change with depth

5. Stable gases are those that pass from the atmosphere into the ocean until they reach saturation. Do cold or warm waters hold more dissolved gasses? (1 point)
    a) Cold Waters
    b) Warm Waters

6. Over geologic time scales, When organic matter is buried, oxygen levels increase in the atmosphere. What is the basic chemical reaction that describes this? Provide a brief explanation why you chose this equation. (4 points, +1 for equation & +3 for explanation)

$$CO_2 + H_2O \rightleftharpoons CH_2O + O_2$$

This question is purposefully misleading. Looking at the equation, burying Organic matter would stop this reaction from happening - making O_2 levels look like they increase.

VII. Formation of fringing reefs, barrier reefs, and atolls (18 points)

1. Name 3 conditions for coral growth. (1 point)
   Any three: Adequate sunlight, gentle wave motion, nutrient-rich water, clear and warm water, solid substrate for anchoring, water pH between 8.4 and 7.7
2. How does coral's symbiotic relationship with zooxanthellae work? [Supervisor recommendation: What do they exchange?] (2 points)
   Coral gives zooxanthellae shelter in return for the glucose/food photosynthesized by the algae
3. Describe the stages of evolution needed for an island reef to become an atoll. (3 points)
   Polyps attach to rocky substrate around island, form a fringing reef. Island begins to sink due to subsidence, but coral reef continues to grow, so a lagoon develops between island and coral. Once the island totally subsides, a ring of coral (atoll) surrounding a deep lagoon is left behind.
4. What is the main nutrient/chemical required for coral reefs to build their skeletons? What happens to this chemical over extremely long periods of time? (2 points)
   $CaCO_3$ or calcium carbonate or calcite; becomes limestone
5. What are patch reefs and where are they found relative to a fringing reef? (2 points)
   Small, isolated reefs that grow up from the open bottom of the island platform or continental shelf. Found in the shallow lagoon behind the back reef or closer to shore/behind the fringing reef
6. Which section of a fringing reef has the least biodiversity? (1 point)
   a) Lagoon
   b) Reef flat
   c) Fore-reef slope
   d) Reef crest

7. Are reefs typically high-energy environments or low-energy ones? Why? (3 points - 1 point for identification of high/low energy, 2 points for why)
   Low-energy because the corals cannot resist erosive wave action and will be broken or unable to attach to substrate in high-energy environments. High energy env. also have more displaced sediment which prevents corals from photosynthesizing.
8. At the end of the Devonian Period, around 356 million years ago, there was a major extinction event that killed almost all corals. Researchers refer to the extinction as the Kellwasser event. Hypothesize what might have caused the extinction of corals at that time and why. [Supervisor recommendation: A wide range of answers will be accepted.] [TieBreaker 5] (4 points - 1 point for potential event & 3 points for reasoning)
   Accept any of the following: Global cooling/glaciation, extraterrestrial impact causing various phenomena, large-scale volcanic eruption
   Reasoning: cooling/glaciation = temperatures too low for corals; asteroid = dust blocked sun, caused cooling & no photosynthesis; volcanism = same as asteroid
   [Supervisor note: if in doubt when correcting, ask me]

VIII. Waves: Motion, height, wavelength, period, fetch, swell, surf, and tsunamis (19 points)

1. What's wrong with the phrase "tidal wave"? What is it actually referring to? [Supervisor recommendation: describe the causes.] (2 points)
   "Tidal wave" refers to the tides which are caused by the gravitational pull of the sun and moon. It is actually referring to a tsunami, which is caused by tectonic displacement.
2. What is the source of energy for ocean waves? (1 point)
   a) **The sun**
   b) The moon
   c) The wind
   d) Gravity
3. What factors affect the height of an ocean wave? (2 points)
   Fetch, wind speed and wind duration
4. How do water particles move under the surface of the wave? How does this phenomenon affect things that float at the surface? (3 points)
   Water molecules move in circles. An object floating at the surface will remain in the same position, but will move up and down with the waves.
5. What are oceanic Rossby waves? Where in the vertical structure of the ocean do they move? [TieBreaker 4] (4 points - 2 points for definition, 2 points for movement location)
   Rossby waves are planetary waves. They are a type of inertial wave that occurs in rotating fluids, and are caused by the rotation of the Earth. They move in the thermocline layer of the ocean.
6. A tsunami has been detected in the southwestern Pacific Ocean. It is passing through the Marianas Trench at Challenger Deep. (7 points - part a, 2 points for formulas, 1 point work, 2 points for answers; 2 points for part b, work and answer)
   a. What are its speed and height at that location, given that Challenger Deep is 11.034 kilometers in depth? Give the speed in m/s and the height in meters.
   b. Once you have calculated the speed of the tsunami, calculate how many minutes it will take to reach Taiwan.

   Tsunami speed = sqrt(9.8*depth), height = 1/sqrt(water depth), speed = 328.84 m/s, height = 0.0095 m; distance to Taiwan from Challenger Deep = 2300 to 2400 km, tsunami will take 116.57 - 121.64 minutes to reach Taiwan.

IX. Surface currents: Warm and cold currents, Coriolis effect, and gyres [11 points]

Ha! You think you got away with less points/questions in this section, just you wait……

1. Mesoscale Eddies are the oceanic equivalent to storms and are subject to the coriolis effect. What direction does a warm anticyclonic eddy rotate in the Northern Hemisphere? (2 points)
    a) Clockwise
    b) Backwards
    c) Counterclockwise
    d) Forward

2. Why are Mesoscale Eddies important (List as many reasons as you can)? [Tiebreaker 6] (0 points)

Transport, heat, salt, carbon & contain half the kinetic energy in ocean circulation
Tiebreaker Points: +1/reason.

3. Labeling Surface Currents: Yeah, we won't ask you mindless questions about these, look 'em up on your own time. Tell us a funny story instead. (0 points)

4. True or False? The Coriolis Force is a real force. (1 point)

Nope(False)

5. In the Northern Hemisphere, which way do ocean currents veer? (1 point)
    a) Left
    b) Right
    c) Upside down and sideways

6. Theoretically, if an ocean current at the surface of the ocean was traveling quickly east parallel to the equator(Say, 30 degrees North), which way would the current veer(Towards or Away from the Equator)? Why? (Hint: What causes the coriolis effect and would that be in play here?) A good explanation is needed here. (7 points)

1) 'Centripetal acceleration is defined as the acceleration needed to keep an object moving in a circle at a particular radius.'
2) Essentially, if you go faster than centripetal acceleration says, you increase your radius and vice-versa.
3) Objects moving east are going faster, so they want to travel outwards from the Earth's axis.

4) Unfortunately, ocean currents can't go outward, and have to find a different way of increasing their radius. This means traveling towards the equator.

+1 - For some mention of centripetal acceleration or the formula
+2 - Recognizing that radius would increase because the current velocity has increased
+2 - Recognizing the current could not travel upward
+2 - Recognizing that the current would travel towards the Equator to increase radius.

X. Ekman and geostrophic balances [21 points]

1. What is the net angle displacement caused by the Ekman Spiral? (1 point)
    a) 0°
    b) 30°
    c) 45°
    d) 90°

2. There are two major drivers of gyre rotation. Wind-drive currents and one other process. Explain that entire process. Answer should include: (Geostrophic Bulge & Coriolis Effect) [Supervisor Note: We expect a thorough explanation. A list explanation is fine.] (10 points)[Tiebreaker 1]

1) Coriolis Force pushes wind-driven currents towards center of ocean basins.
2) Causes Pile-Up. A 'hill' called the geostrophic bulge, a delicate balance
3) Gravity pushes water back down the hill.
4) B/C Coriolis Force happens, that water veers to the right, creating a circular motion pattern - a Gyre.

Roughly,
+2.5 - Coriolis Force pushes wind-driven currents towards center of ocean basins.
+ 2.5 - Causes Pile-Up. A 'hill' called the geostrophic bulge, a delicate balance
+ 2.5 - Gravity pushes water back down the hill.
+2.5 - B/C Coriolis Force and Ekman transport, that water veers to the right, creating a circular motion pattern - a Gyre.

Supervisor Note: While this is more basic than other hard questions, the point value is higher because this is a very central topic in DP.

3. What causes western intensification? [Supervisor note: You can assume that you and the grader already understand the processes involved in Question 2.] [Tiebreaker 2] (10 points)

Using processes in 2, western intensification is caused because the geostrophic bulge is shifted to the west in major ocean basins. Since the same amount of water must pass through both sides of the gyre, the water on the west side is squeezed and forced to move faster and deeper, while the east side has more space for water to flow through and can be fairly shallow.

The bulge is shifted because the coriolis force is much more prevalent at higher latitudes, causing the ocean currents in higher latitudes to veer much earlier than equatorial currents. This forms the bulge more west than the center of the ocean basin.

Roughly,
+5 Identifying Coriolis Force is stronger at higher latitudes(+2.5) and causes currents at higher latitudes to veer earlier forming the bulge west of the center(+2.5).
+5 Explanation of how the same amount of water passes through both sides of the Gyre(+2.5) and how this means the western current ‘intensifies’ because of this(+2.5)

XI. Coastal currents: longshore currents, rip currents, and upwelling (12 points)

1. Describe the effects of upwelling on the fishing industry. Why does upwelling have this effect? (3 points - 1 point for effect, 2 points for why)
   Upwelling benefits the fishing industry by increasing fish yields. Upwelling brings nutrients and cold water closer to the surface, which attracts fish.
2. What is a longshore current? How are they formed? (2 points - 1 point definition, 1 point formation)
   A longshore current is a coastal current that moves parallel to shore. Longshore currents are formed when waves break at an angle to the shore, sending part of their energy, and therefore a current, parallel to the coast.
3. Why are longshore currents detrimental to coasts with low-energy environments? (2 points)
   Low-energy environments tend to have softer sand that is more prone to erosion. Longshore currents can sweep large amounts of the sand out to sea and cause a receding coastline.
4. Riptides are the incorrect name for what phenomenon? How are these actually formed? (3 points - 1 point name, 2 points formation)
   Rip currents; actually form when water is drawn back to the ocean through a break in a sand bar under the water, which creates suction and can pull large amounts of sand (or a person) out to sea.
5. What kind of underwater topography can make an area more prone to having rip currents? Select all that apply (2 points)
   a) **Inshore holes**
   b) Reef crests
   c) **Broken sandbars**
   d) Eroded shallows

XII. Deep ocean circulation, ocean overturning, and water masses [13 points]

1. Why is deep water in the Atlantic much younger than deep water in the Pacific or Indian oceans? (3 points)

Deep water masses only form in the Atlantic. This is because the Atlantic has higher salinity than the Pacific and that higher salinity, when it cools, is dense enough to sink to a greater depth

2. What are the three major Deep/Intermediate Water Masses? (2 points, No Partial Credit)
   NADW, AIW, AABW

3. Do deep water masses form at high or low latitudes? (1 point)
   a) High Latitudes
   b) Low Latitudes
   c) They form everywhere
   d) They simply…exist

4. What two things define a water mass? (1 point)

Temperature & Salinity

5. In Broecker et. al. (1990a), it is noted that higher Atlantic salinities are the result of a net transfer of water vapor from the Atlantic to the Pacific over the Isthmus of Panama. In the absence of other processes affecting oceanic salinity, this would raise the salinity of the Atlantic by about 1 salinity unit each 1000 years. Since this obviously isn't happening, the Atlantic must be exporting salt to compensate for the lost freshwater. What process is accomplishing this? [Supervisor Recommendation: Don't write more than 10 words] (3 points)

Production and export of NADW

6. What is the name of the ~~blender~~ ocean current sometimes referred to as the "Giant Mixmaster" that plays an instrumental role in mixing NADW, PDW, and other deep water masses leading to redistribution of deep water into the Indian and Pacific Oceans? [Hint: Don't think too deeply, are there even any currents that could distribute water over those two oceans?] (3 points)

Antarctic Circumpolar Current

XIII. Relationships between fisheries and ocean circulation (e.g., upwelling, El Niño, Pacific Decadal Oscillation) [11 points]

1. Does La Nina cause an increase or decrease in upwelling the eastern equatorial Pacific? (1 point)
    a) Decrease
    b) Increase
    c) Neither
    d) Both

2. How does El Nino impact Australia in terms of precipitation? (1 point)
    a) Increase in Precipitation
    b) Decrease in Precipitation
    c) No Change in Precipitation
    d) Precipitation only varies when I say it does

3. SOI(Southern Oscillation Index) is a standardized teleconnection index that measures the difference in sea-level pressures between Tahiti and Darwin(Near Australia). Specifically, SOI = $\frac{Standardized\ Tahiti - Standardized\ Darwin}{MSD}$. It has important uses in weather modeling. If SOI is negative, does that mean we are in El Nino or La Nina? Why? [Supervisor Note: If you're interested in teleconnections indexes or weather modeling, reach out to us!] (4 points, +1 for which stage, +3 for explanation)

El Nino b/c El Nino is weakening/reversal of trade winds which by definition mean an increase in SLP in Darwin, which would make the equation negative.

4. What is the Pacific Decadal Oscillation? [Supervisor Recommendation: Don't spend too much time on this] (2 points)

'robust, recurring pattern of ocean-atmosphere climate variability centered over the mid-latitude Pacific basin. The PDO is detected as warm or cool surface waters in the Pacific Ocean, north of 20°N. Over the past century, the amplitude of this climate pattern has varied irregularly at interannual-to-interdecadal time scales (meaning time periods of a few years to as much as time periods of multiple decades).'
Combination of several factors.

5. While PDO and El Nino are fun little oscillations, there are many oscillations that have massive impacts across the globe. One such oscillation is the North Atlantic Oscillation(Local manifestation of Arctic Oscillation). Name another major oscillation in the world! (2 point)

Antarctic, Atlantic Multidecadal, Indian Ocean Dipole, Madden-Julian, North Pacific Gyre, PNA, etc..

6. What are the 4 major eastern boundary currents in which coastal upwelling primarily occurs? (1 point)

Peru, California, Canary, Benguela.

7. What is a fish? [0 points]

XIV. Story Problem: Tales of O'Neer, Vol. II (26 points)

Assistant researcher O'Neer is an intern aboard the small research vessel Dynamic Planet. O'Neer is a very interesting person - his hobbies involve oceanography and eating pie. He bribes his research supervisor with said pie in order to take this boat out for an oceanographic study cruise. He sets off from Cape Hatteras, North Carolina.

The first thing O'Neer does when he gets a significant distance out to sea is dump a bottle of (biodegradable) dye into the water. He assumes that surface currents will eventually carry this dye to _Britain/England/Ireland_(1) (1 point). He further hypothesizes that the dye will travel primarily by the _Gulf Stream_(2) (1 point) current.

O'Neer decides that he would like to go someplace warm as his first destination, so he travels to the Strait of Gibraltar, between Spain and Morocco. O'Neer observes a strange phenomenon as he entered the Strait of Gibraltar - the complicated instruments on his boat showed a series of waves below the surface that were totally uncorrelated with the actual surface waves. He consults a local scientist, Sarah, who observes a similar phenomenon in clouds. She says they are _(oceanic) internal waves_(3) (2 points).

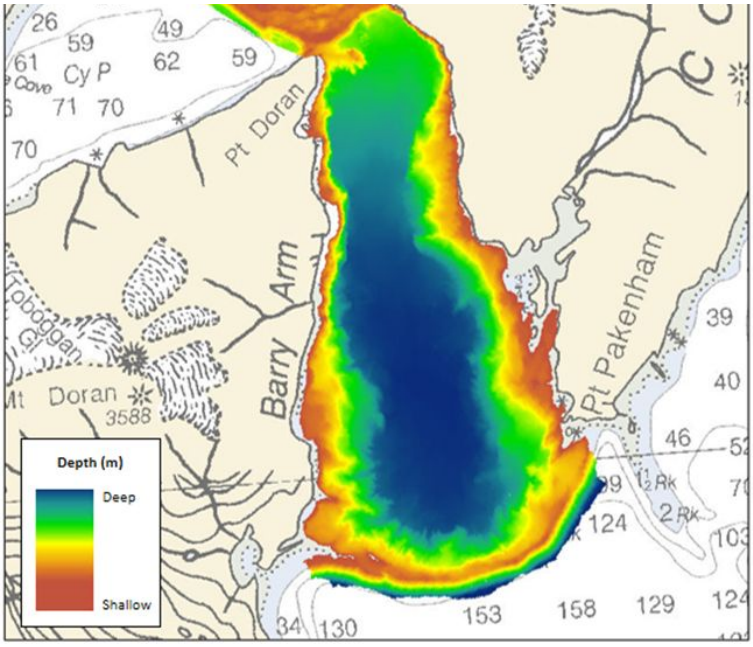
After his brief adventure in Africa, O'Neer heads back across the Atlantic Ocean towards Newfoundland, Canada. On the way, he takes a couple of bathymetric SONAR scans and comes up with this graph:

He concludes that the bulge around 4000-4500km is _the Mid-Atlantic Ridge_(4) (1 point) and the little dips and peaks within that region must be _transform boundaries/faults_(5) (1 point).

As O'Neer finally nears Newfoundland, he sees some icebergs floating in the ocean. Due to his handy navigating skills and the advent of modern technology, he manages to avoid them. As O'Neer wonders why his research vessel was so close to going the same way as the

RMS Titanic, he remembers that the _Labrador Current_(6) (1 point) carries the icebergs here. He decides this is as good a place as any to collect some data and grabs his Niskin bottle and CTD from below deck. What types of data can O'Neer collect? Give two examples. _Temperature, pressure, conductivity, depth, ion concentration from water sample_(7) (2 points)

From Newfoundland, O'Neer travels northeast towards Norway. He travels inland and takes another bathymetric scan, getting this profile (ignore the name labels):



He knows that this formation is a _fjord_(8) (1 point), caused by _glaciers/glacial erosion_(9) (1 point). O'Neer describes the salinity distribution of this basin as _high salinity at the bottom/in the basin and strongly vertically stratified_(10) (2 points). After restocking in Norway, he continues to sail through the Arctic Ocean. He observes many sea arches and sea stacks, caused by _wave erosion/weathering_(11) (1 point) of a _headland_(12) (1 point). O'Neer reemerges into the Pacific Ocean through the Bering Strait, where he deploys a bottom corer. Give two examples of the types of data he could collect from the sediment sample he gets: _accept data types to do with bottom sediments or benthic organisms, data from bottom waters _(13) (2 points).

O'Neer's next destination is Australia, where he hopes to have a relaxing vacation before he heads back home. As he sails along the coast of Japan, he observes a tidal pattern that is recorded below. He deduces that this is a _mixed semidiurnal_(14) (1 point) tide cycle.

Date	Time	Tide Height (ft)
11/17	23:54	0.4
11/18	06:00	3.9
11/18	10:12	3.1
11/18	15:24	4.8

11/18	19:33	2.7
11/18	23:16	0.2
11/19	06:52	3.7
11/19	10:44	3.2
11/19	16:00	4.6
11/19	20:09	2.8
11/20	0:00	0.3
11/20	07:52	3.5

In Japan, O'Neer also observes two different types of beaches: the first is very rocky and exposed, with large sand grains and a short beach face, while the second has a very wide beach face and fine sand grains. He realizes that the first type is a _high_(15) (1 point) energy coastline and the second is a _low_(16) (1 point) energy coastline.

When he finally reaches the coast of Australia, O'Neer notices that surfers love a certain type of breaking waves that occur. He observes that the crests of these waves curl over themselves, creating a barrel of air between the crest and trough before the wave collapses. He remembers that one of his professors said these were _plunging_(17) (1 point) waves which happen in areas where the ocean floor is/has _steep/has sudden depth changes_(18) (2 points).

While vacationing on a beach in Australia, O'Neer observes that a thick band of shoreline is suddenly exposed, as though the water pulled back significantly. Several rocks and shells are exposed in the sand that would normally be submerged. He decides to go collect some souvenirs for his professors back home, but when he steps into the now-shallower water, he finds that the pull of the water is so strong that he trips. O'Neer is sucked out to sea very quickly. What has happened to him? _He has been caught in a rip current_(19) (1 point) It is up to you, the reader, to rescue O'Neer. Write him a brief message about how to escape his current danger, and it will be transported to him as soon as you finish this test: _O'Neer should swim sideways, parallel to the coast, until he escapes the rip current._(20) (2 points)

In the future, assuming you have given O'Neer the correct lifesaving advice, he will travel back home. He will (hypothetically, of course) dock back at Cape Hatteras, North Carolina, given he doesn't get shipwrecked by the shifting sandbars. If you would like to see O'Neer's future adventures, search for our tests.