MARS6080-4080 – Fall 2019 Midterm #2

Student Name: _____KEY_____

This midterm is worth 100 points, will take 75 minutes, and it is worth 20% of your grade. You may use a calculator, but not a cell phone. If you need more paper, let me know.

Part 1: Multiple Choice (1 points each; 30 points total)

1) Given a constant zonal wind stress, Ekman surface current speed: ___

a. increases at higher latitude
b. declines at higher latitude
c. Does not change with changing latitude

2) Given a constant zonal wind stress, the Ekman layer depth: ___

a. increases at higher latitude
b. declines at higher latitude
c. Does not change with changing latitude

3) Given a constant zonal wind stress, current speed in the Ekman layer:___

a. increases at higher latitude
b. declines at higher latitude
c. Does not change with changing latitude

4) A dynamic meter is equal to: _____

a. 1 joule/kg
b. 10 joules/kg
c. 10 m^2/sec^2
d. Both b and c

5) ___ subtropical gyres have anticyclonic rotation.

a. All
b. None
c. Northern hemisphere
d. Southern hemisphere

6) ___ subtropical gyres have clockwise rotation.
   a. All
   b. None
   c. Northern hemisphere
   d. Southern hemisphere

7) ___ subpolar gyres have anticyclonic rotation.
   a. All
   b. None
   c. Northern hemisphere
   d. Southern hemisphere

8) ___ subpolar gyres have anticlockwise rotation.
   a. All
   b. None
   c. Northern hemisphere
   d. Southern hemisphere

9) Ekman spirals do not exist: _____
   a. in high latitude oceans
   b. in marginal seas
   c. at the equator

10) The depth of no motion is typically estimated to be at a depth of: _____
   a. 100 to 200 m
   b. 1000 to 1200 m
   c. 1500 to 2000 m
   d. below 4000 m

11) Which of the following quantities can be used to estimate vertical flow in the ocean?_____
   a. coriolis force
   b. pressure gradient force
   c. wind stress
   d. wind stress curl

12) The rate of change in the coriolis force with latitude (*i.e.*, df/dy): ___
   a. increases with increasing latitude
   b. decreases with increasing latitude
   c. remains constant with increasing latitude

13) The eddies lee of the Big Island: ____
   a. are always cyclonic
   b. are always anticyclonic
   c. are cyclonic and anticyclonic

14) Surface currents around Hawaii are dominated by: ____
   a. the NEC
   b. wind
   c. the NEC and wind

15) Barotropic conditions are defined by:____
   a. isobars and isopycnals are parallel
   b. isobars and isopycnals are not parallel
   c. only the isobars are parallel to each other
   d. only the isopycnals are parallel to each other

16) Baroclinic conditions are defined by:____
   a. isobars and isopycnals are parallel
   b. isobars and isopycnals are not parallel
   c. only the isobars are parallel to each other
   d. only the isopycnals are parallel to each other

17) Barotropic conditions are found:____
   a. throughout the ocean (this is the typical condition)
   b. only in well-mixed shallow areas
   c. only in the deep ocean
   d. in both well-mixed shallow areas and in the deep sea

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   a. throughout the ocean (this is the typical condition)
   b. only in well-mixed shallow areas
   c. only in the deep ocean
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19) Western Boundary Currents:____
a. are similar in the Atlantic and Pacific Oceans only
b. are different in the Indian Ocean and Arctic Ocean
c. are the same in all oceans

20) Eastern Boundary Currents:_____
a. are similar in the Atlantic and Pacific Oceans only
b. are different in the Indian Ocean and Arctic Ocean
c. are the same in all oceans

21) Coastal upwelling:_____
a. only occurs in eastern boundary currents
b. only occurs in western boundary currents
c. occurs in both eastern and western boundary currents
d. does not occur in eastern or western boundary currents

22) Countercurrents:_____
a. only occur in eastern boundary currents
b. only occur in western boundary currents
c. occur in both eastern and western boundary currents
d. do not occur in eastern or western boundary currents

23) _____ are fast and deep.
a. eastern boundary currents
b. western boundary currents
c. both eastern and western boundary currents
d. neither eastern nor western boundary currents

24) _____ are shallow and slow.
a. eastern boundary currents
b. western boundary currents
c. both eastern and western boundary currents
d. neither eastern nor western boundary currents

25) Deep and shallow surface waves are defined, respectively, by:____
a. depth > L /2 and depth > L/20
b. depth < L /2 and depth < L/20
c. depth > L /2 and depth < L/20

26) Internal Waves: _____
a. only happen when the water is stratified
b. are always progressive waves
c. are always standing waves
d. both a and b are true

27) The period of planetary waves is: _____
a. longer than 30 days
b. longer than 100 days
c. longer than 365 days

28) Which of these statements are true about Rossby waves: _____
1. propagate to the west
2. propagate to the east
3. move towards the equator, after reaching the ocean boundary
4. move towards the pole, after reaching the ocean boundary

a. 1 and 3
b. 1 and 4
c. 2 and 3
d: 2 and 4

29) Which of these statements are true about Kelvin waves: _____
1. propagate to the west
2. propagate to the east
3. move towards the equator, after reaching the ocean boundary
4. move towards the pole, after reaching the ocean boundary

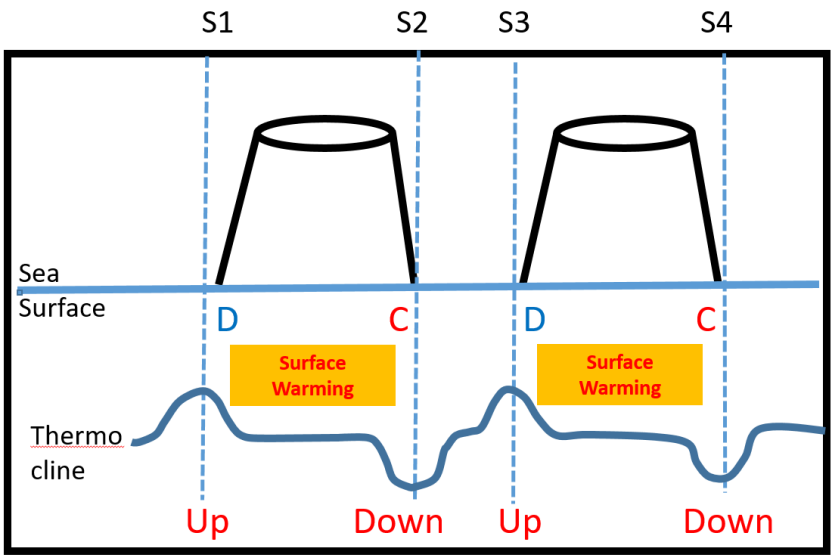
a. 1 and 3
b. 1 and 4
c. 2 and 3
d: 2 and 4

30) Why are there two tidal bulges on the Earth: ___
a. because the gravitational pull of moon and sun are at 90 degrees
b. because of syzygy
c. because of quadrature
d. due to the balance of inertia and gravity

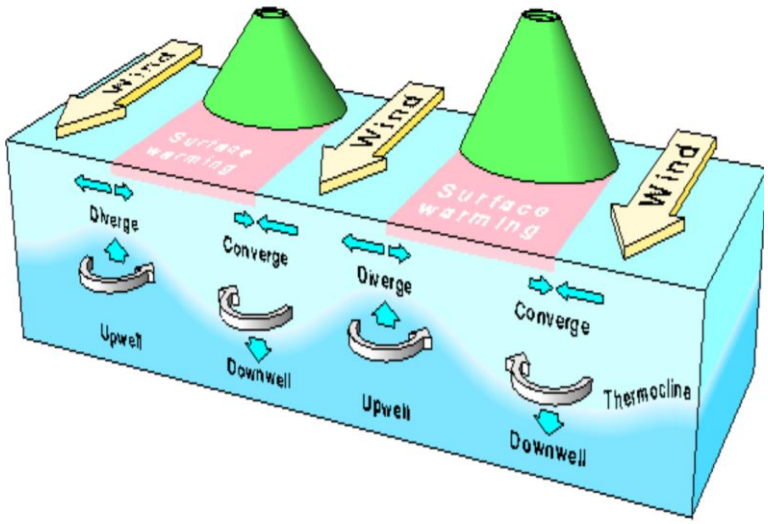
Part Two: Equations and interpretation (50 points total).

31) Explain the "island wind effects" associated with the passes between the Main Hawaiian Islands. For these stations (S1 – S4) , do the following: (A) show areas of surface convergence and divergence, by writing "C" and "D" along the sea surface line (+ 4 points); (B) draw the changes in the depth of the thermocline (+4 points), downwind from these two islands; (C) draw the two locations where you expect the warmest sea surface temperature (+1 point each)

Series of alternating convergences (downwelling) and divergences (upwelling)



And this the diagram from Dr. Kahng's lecture



32) Explain which two forces are balanced in geostrophic flow (+2 points), and list the four key assumptions underlying this theory (+2 points each):

The 2 forces are: _Coriolis_ and _Pressure Gradients_

The 4 assumptions are:

Geostrophic Flow - Equations

Derived from the equations of motion, using Four Key Assumptions:

1. Pressure force balances coriolis force.
2. No acceleration (dv/dt = 0 & du/dt =0) (NOTE: Water moving at constant speed).
3. Horizontal velocities much greater than vertical velocities (*i.e.*, w << u & v).
4. Friction is small and can be ignored.

33A) Write the equations of motion for u and v, assuming there is acceleration and friction (5 points each).

acceleration		pressure gradient force ↓		Coriolis force ↓		contributions from other forces ↓
$\frac{du}{dt}$	=	$\frac{1}{\rho}\left(-\frac{dp}{dx}\right.$	+	$\rho f v$	+	$\left.F_x\right)$
$\frac{dv}{dt}$	=	$\frac{1}{\rho}\left(-\frac{dp}{dy}\right.$	−	$\rho f u$	+	$\left.F_y\right)$

33B) Work out units for the balance of acceleration and pressure gradient (2.5 points):

$-\frac{\partial P}{\partial x}$ rate of change in pressure with distance (in this case zonal x-direction)

Pressure has units of pascals $\frac{kg}{m\,sec^2}$

$$\frac{\text{Pascals}}{m} = \frac{kg}{m^2\,sec^2}$$

$$\frac{1}{\rho} \cdot \frac{\partial P}{\partial x} = \frac{m^3}{kg} \cdot \frac{kg}{m^2\,sec^2} = \frac{m}{sec^2} \text{ acceleration}$$

33C) Work out units for the balance of acceleration and Coriolis force (2.5 points):

$+\rho f v$

ρ = density kg/m^3

f = Coriolis parameter $\frac{1}{sec}$

V = Velocity meridonal m/sec

$$\frac{kg}{m^3} \cdot \frac{1}{sec} \cdot \frac{m}{sec} = \frac{kg}{m^2\,sec^2}$$

$$\frac{1}{\rho} x + \rho f v = \frac{m^3}{kg} \cdot \frac{kg}{m^2\,sec^2} = \frac{m}{sec^2} \text{ acceleration}$$

(note + sign)

33D) Work out units for the balance of acceleration and friction (2.5 points):

$\rho A_z \frac{\partial^2 u}{\partial z^2}$ or density * eddy viscosity * rate of change of rate of change in velocity

$$\frac{Kg}{m^3} \cdot \frac{m^2}{sec} \cdot \frac{1}{sec\, m} = \frac{Kg}{m^2\, sec^2} \qquad \frac{m^3}{Kg} \cdot \frac{Kg}{m^2\, sec^2} = \underline{\underline{\frac{m}{sec^2}}}$$

kinematic viscosity

$\frac{\partial^2 u}{\partial z^2}$

34A) List the 5 assumptions underlying the calculation of the Ekman equation (0.5 points each)

1. No Acceleration (i.e., steady consistent wind)
2. Constant A_z (eddy viscosity in vertical)
3. No boundary friction (*i.e.*, no horizontal boundaries)
4. No bottom friction (*i.e.*, infinite depth)
5. f (coriolis parameter) varies very little with latitude. Basically, constant Coriolis force acts on the water

34B) After these assumptions, what two forces are balanced in the Ekman equation. For full credit, show the equations for u and v (5 points total)

NOTE: Coriolis and Friction balance each other

Ekman's Equation

No Acceleration
No Pressure Gradient
Coriolis = Friction

$$\frac{du}{dt} = \frac{1}{\rho}\left(-\frac{\partial p}{\partial x} + \rho f v + \rho A_z \frac{\partial^2 u}{\partial z^2}\right) \qquad \frac{dv}{dt} = \frac{1}{\rho}\left(-\frac{\partial p}{\partial y} - \rho f u + \rho A_z \frac{\partial^2 v}{\partial z^2}\right)$$

$$f v + A_z \frac{\partial^2 u}{\partial z^2} = 0 \qquad -f u + A_z \frac{\partial^2 v}{\partial z^2} = 0$$

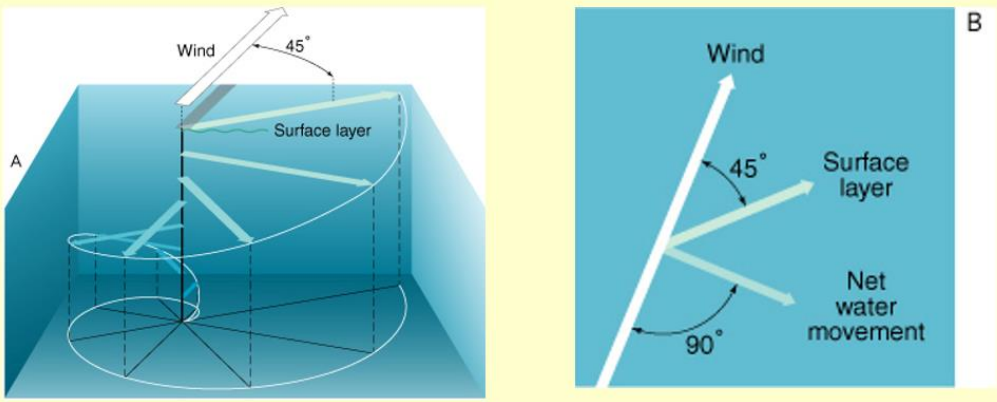
Solved these equations for V and U as a function of depth

Solutions to these equations are very complex

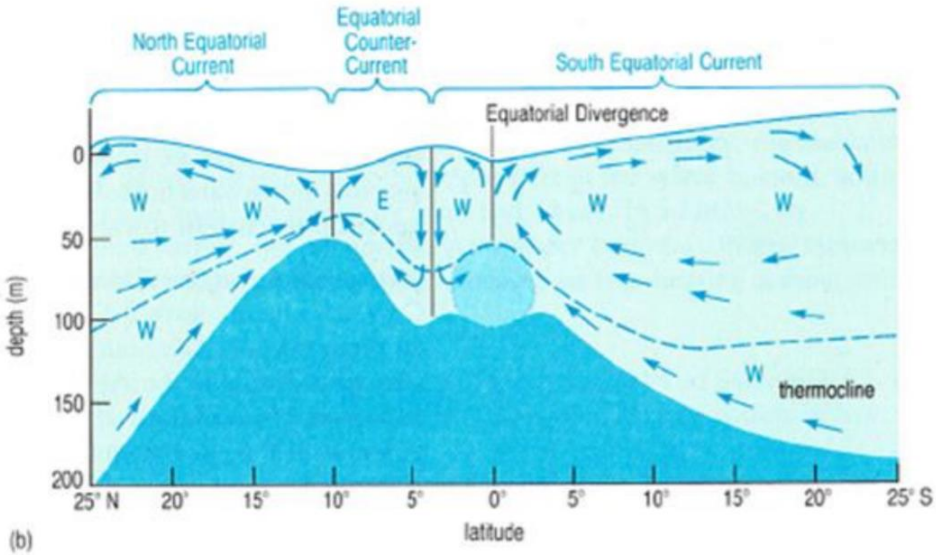
34C) Draw the Ekman spiral in the northern hemisphere and explain what s happening to the surface layer and to the entire Ekman layer (+0.25 points).

The Ekman Spiral

- Surface current 45° to direction of wind
- Spiral water motion, down to 20 – 30 m
- Decreasing current velocity with depth
- Integrated water motion (*i.e.*, net water transport) 90° to direction of wind



35) Draw a cross-section of equatorial circulation, showing the depth and latitude of the following features: thermocline, NEC, EUC, SEC, ECC (2 points each). NOTE: for full credit, think carefully about the depth and latitude range you show in your drawing.



Part 3: Physical-Biological Interactions (20 points total)
Please answer the questions within the space provided

36) Explain what is the Costa Rica dome and why it is biologically important (6 points). For full credit, explain: (a) what oceanographic processes cause this feature, (b) how do these physical processes affect ocean productivity, and (c) what biological responses occur at this feature (2 points each).

The Costa Rica dome is a region of shallower thermocline and upwelling, located at 90 deg. W and 10 deg. N., associated with the anticlockwise vorticity associated with equatorial countercurrent (flowing east) flowing into the northern equatorial current (flowing west). Thus, this is not a coastal upwelling phenomenon. The area is characterized by high localized productivity, and a response in the biomass of primary producers (higher chl-a concentrations), plankton, and nekton, including tunas, oceanic dolphins and blue whales. Because blue whales from the California Current over-winter in the Costa Rica dome, this area is termed the "blue whale cafe".

37) From the class presentations (and associated readings), describe one example where the vertical or horizontal distribution of a pelagic organism was influenced by physical properties (8 points). For full credit: (a) describe what organism was involved, (b) in what oceanographic environment did the study take place, (c) what was the driving water property, and (d) how did the organism respond (2 points each).

Any example, involving sea turtles, sharks, or tunas, would be suitable.

38) Finally, list three ways that internal waves could affect pelagic organisms living in the water column OR that tides could affect benthic organisms living on a coastline. (6 points). For each way, briefly explain what organism would be involved and what ecological process would be influenced. Hint: This question forces you to go beyond the lectures (2 points each).

Any example involving internal wave aggregation / transporting of plankton / larval fish, and tides affecting the submergence of intertidal organisms, with the implications for larval settlement, physical stress, and exposure to predators (like sea stars, octopus, rays) will work.