

USES0 2021

# Open Exam

## Section II



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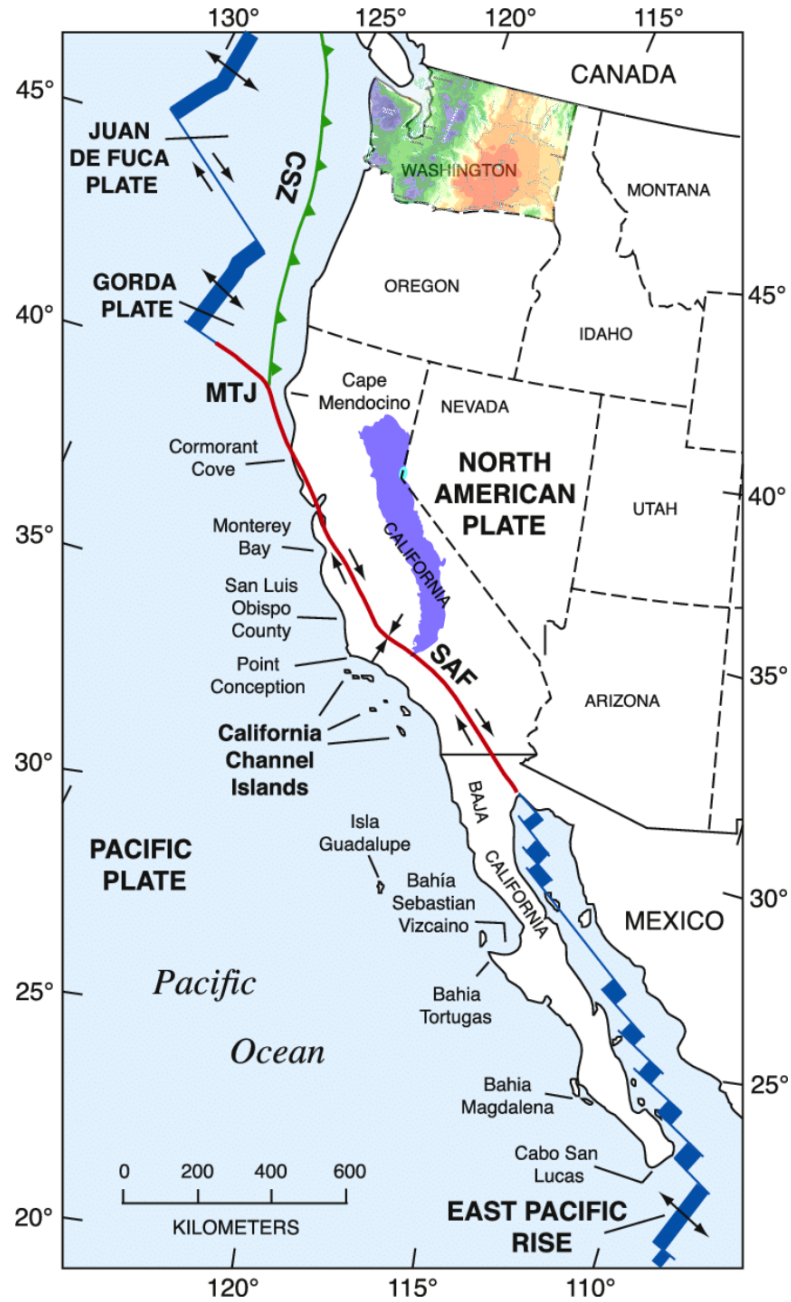
### Instructions:

- Section II is 90 minutes and consists of 5 multipart questions that further assess geoscience knowledge in the form of free response and multiple choice questions
- A non-graphing, non-programmable calculator is allowed; show all work for calculations
- Questions marked with a (\*) may have more than one answer
- For multiple select questions: correct answers earn 1 pt, incorrectly marked answers deduct 1 pt, and unmarked correct answers do not earn nor deduct points

[ANSWER FORM HERE](#)

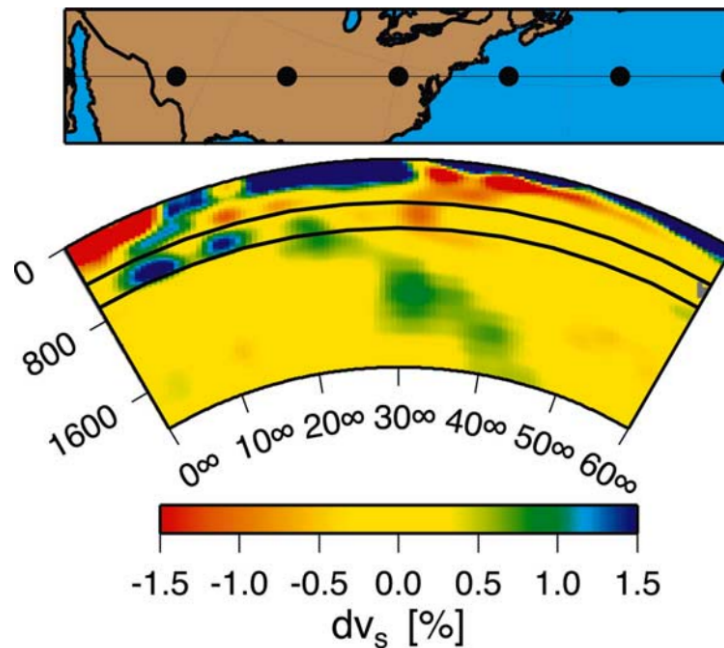
## Problem 1

Question	1	2	3	4	5	6	Total
Points	1	2	3	2	3	1	12 (20%)



**Figure 1:** Tectonic settings in western North America. Abbreviations: SAF, San Andreas Fault; MTJ, Mendocino Triple Junction; CSZ, Cascadia Subduction Zone.

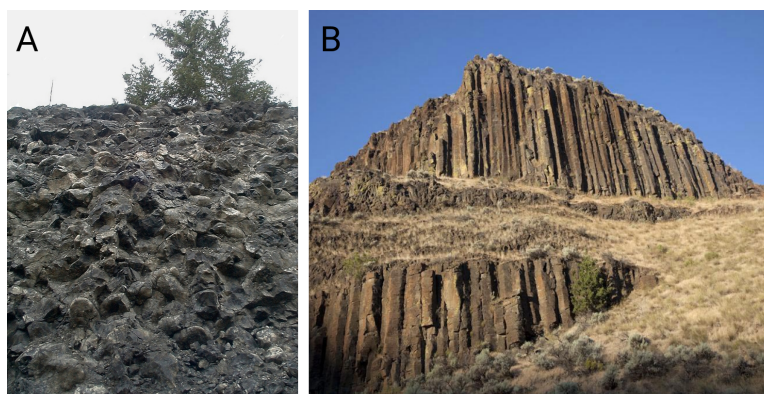
1. (1 point) The Sierra Nevada, marked in violet in Figure 1, is a mountain range in California. Which of the following describes the predominant composition and texture of igneous rocks found in the core of the Sierra Nevada?
    - A. Felsic, coarse-grained
    - B. Felsic, fined-grained
    - C. Mafic, coarse-grained
    - D. Mafic, fined-grained
  2. (2 points) Half Dome is a well-known example of an exfoliation dome, a structure with joints that parallel the surface of the dome. Describe a change in the environment after the initial crystallization of the pluton and how it is responsible for this jointing.
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(Schmid et al., 2002)

**Figure 2:** A seismic tomography cross section along the line in the map above. Positive values of  $dv_s$  represent relatively cold regions in the mantle.

3. While California is mostly bordered by a transform boundary, volcanic activity in the Sierra Nevada is still detected today.
  - (a) (1 point) Identify the green feature sloping down towards the east in Figure 2.
  - (b) (2 points) Describe the mechanism responsible for melt formation in the Sierra Nevada. How does the feature in (a) support this?



**Figure 3:** Two basalt formations in Washington: the Columbia River Flood Basalts and the Crescent Formation Basalts (a Mid-Ocean Ridge Basalt, or MORB), in no particular order.

4. (2 points) Classify A and B as either the Columbia River Flood Basalt or the Crescent Formation. Provide one piece of evidence for the classification.
5. (3 points) A sample from Formation A is crushed and analyzed. The following data are gathered:

$^{39}\text{K}$ mass	1.290 g
$^{40}\text{K}/^{39}\text{K}$ mass fraction	$1.254 \times 10^{-4}$
$^{40}\text{Ar}$ mass	$5.084 \times 10^{-6}$ g
Half-life of $^{40}\text{K}$	$1.248 \times 10^9$ years

Potassium-40 ( $^{40}\text{K}$ ) decays to argon-40 ( $^{40}\text{Ar}$ ), an inert gas that is trapped after crystallization. Assume that  $^{40}\text{Ar}$  does not escape the rock. If Formation B has an age of 16.7 million years (Ma), how many times as old is Formation A than Formation B? Show work for all calculations.

6. (1 point) In Figure 1, Washington state is overlaid with a map of the local precipitation, with warm colors indicating low precipitation. Briefly account for why the eastern half of Washington receives significantly less precipitation than the west.

## Problem 2

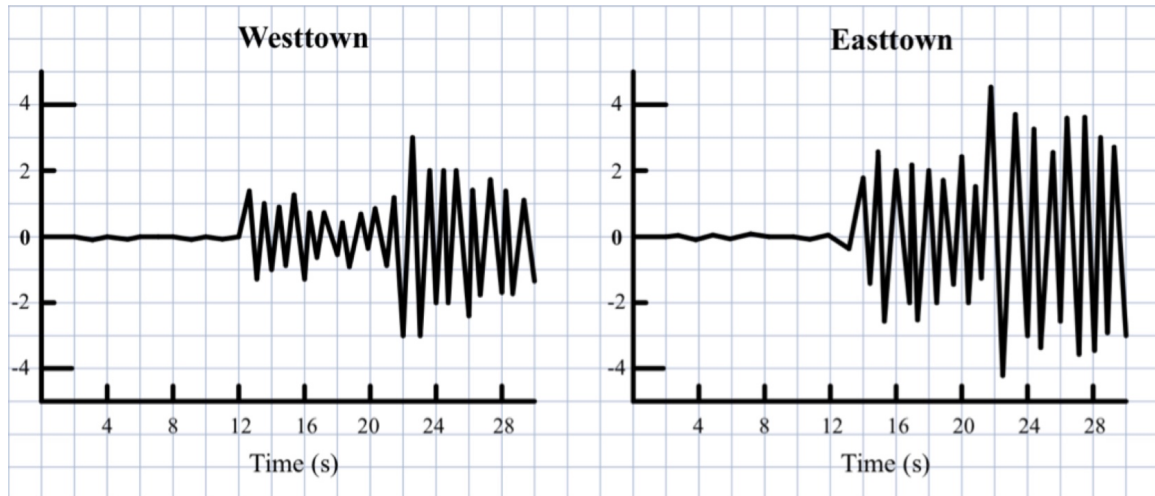
Question	1	2	3	4	5	6	Total
Points	1	3	2	1	2	2	11 (18%)

In the following map, Westtown and Easttown are separated by a normal fault. The red X represents the epicenter of an earthquake the same distance away from both towns. Assume no other faults are located nearby.



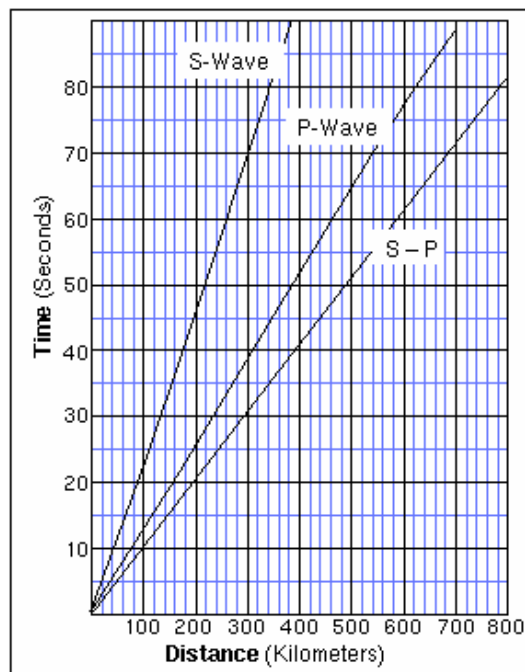
1. (1 point) Identify the type of stress that resulted in the formation of the fault.
2. (3 points) After the earthquake, which town, if any, was uplifted relative to the other town? Justify your answer.
3. (2 points) What additional pieces of information would need to be known to calculate the depth of the earthquake's focus (hypocenter)?
  - I) The strike direction of the fault
  - II) The dip angle of the fault
  - III) Map distance from the epicenter to the fault
  - IV) Map distances from the epicenter to Westtown and Easttown
  - A. I and III
  - B. II and III
  - C. II and IV
  - D. II, III, and IV
  - E. I, II, and III

4. (1 point) Shown below are two seismograms (records of seismic waves) for Westtown and Easttown.

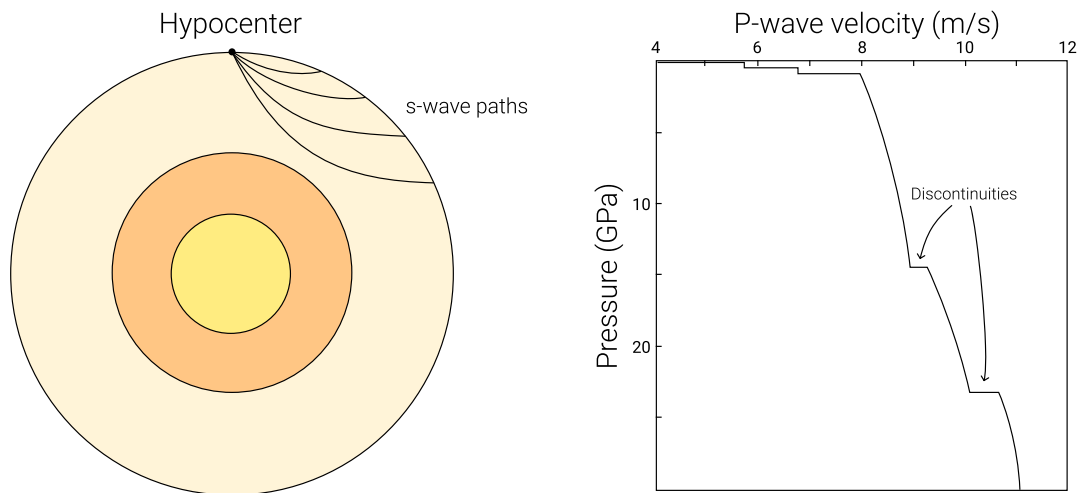


Which of the towns, if any, is more likely to be located on alluvial deposits than solid bedrock?

- A. Westtown, because the amplitude of the seismic waves is lower
  - B. Westtown, because the frequency of the seismic waves is lower
  - C. Easttown, because the amplitude of the seismic waves is higher
  - D. Easttown, because the frequency of the seismic waves is higher
  - E. Neither, because the P-waves arrive at the same time for both towns
5. (2 points) Shown below are travel time curves for S-waves, P-waves, and the SP interval (lag time).



Using the information from both the seismograms and the above chart, how far away is Westtown from the epicenter of the earthquake, in kilometers? Justify your answer.



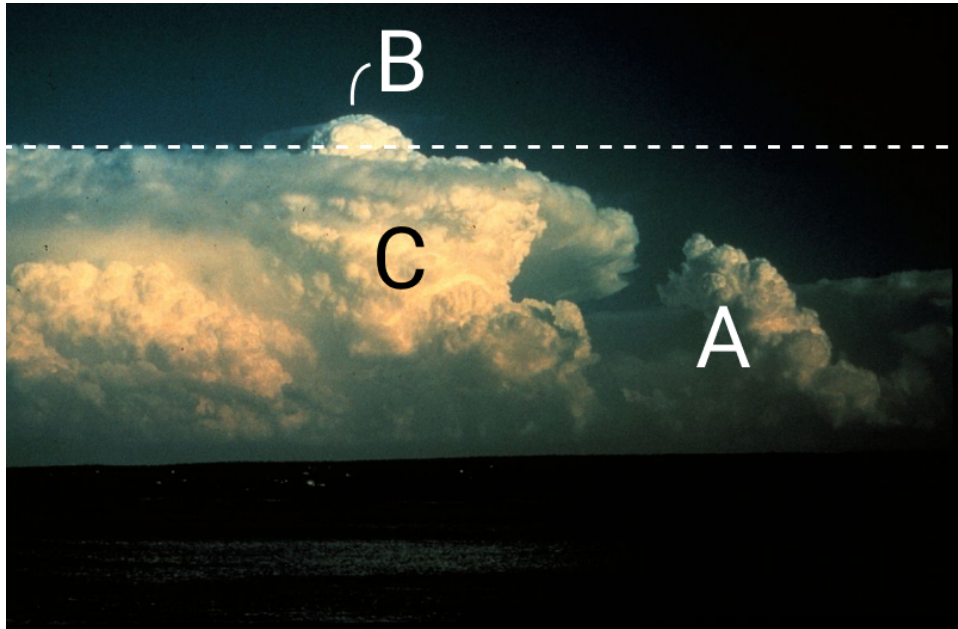
**Figure 4:** (left) S-wave paths through the mantle; (right) P-wave velocity with pressure (depth) in the mantle.

6. (2 points) Give brief explanations to account for the following observations:

- (a) S-wave paths are curved and concave-up towards the surface.
- (b) There are discontinuities in p-wave velocities at certain depths.

### Problem 3

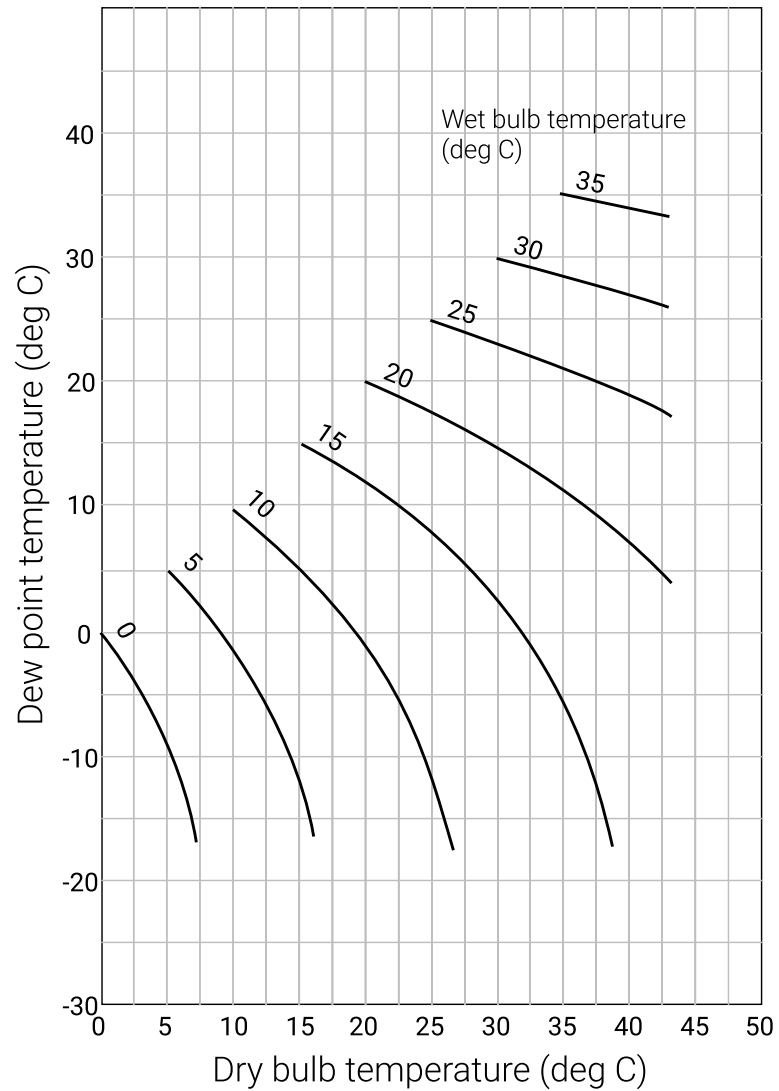
Question	1	2	3	4	5	Total
Points	1	1	3	2	5	12 (20%)



- (1 point) Cloud A is called a cumulus congestus cloud, which is simply a large cumulus cloud. What is the primary direction of motion of the air in cloud A?
- (1 point) What is the name of the dashed line?
- (3 points) Why is most of cloud C limited to elevations below the dashed line? What occurs when a cloud overshoots this line?
- Feature B is called an overshooting top.
  - (1 point) Why does it extend above the dashed line?
  - (1 point) What does this indicate about the condition of the underlying atmosphere?
- A parcel of air at ground level has a dry bulb temperature of  $15^{\circ}\text{C}$  and a wet bulb temperature of  $12.5^{\circ}\text{C}$ . To analyze its interactions with the environment, radiosonde observations and thermodynamic calculations revealed the following parameters:

Environmental lapse rate (ELR)	$7.80^{\circ}\text{C}/\text{km}$
Dry adiabatic lapse rate (DALR)	$9.69^{\circ}\text{C}/\text{km}$
Moist adiabatic lapse rate (MALR)	$6.75^{\circ}\text{C}/\text{km}$
Dew point lapse rate	$2.00^{\circ}\text{C}/\text{km}$

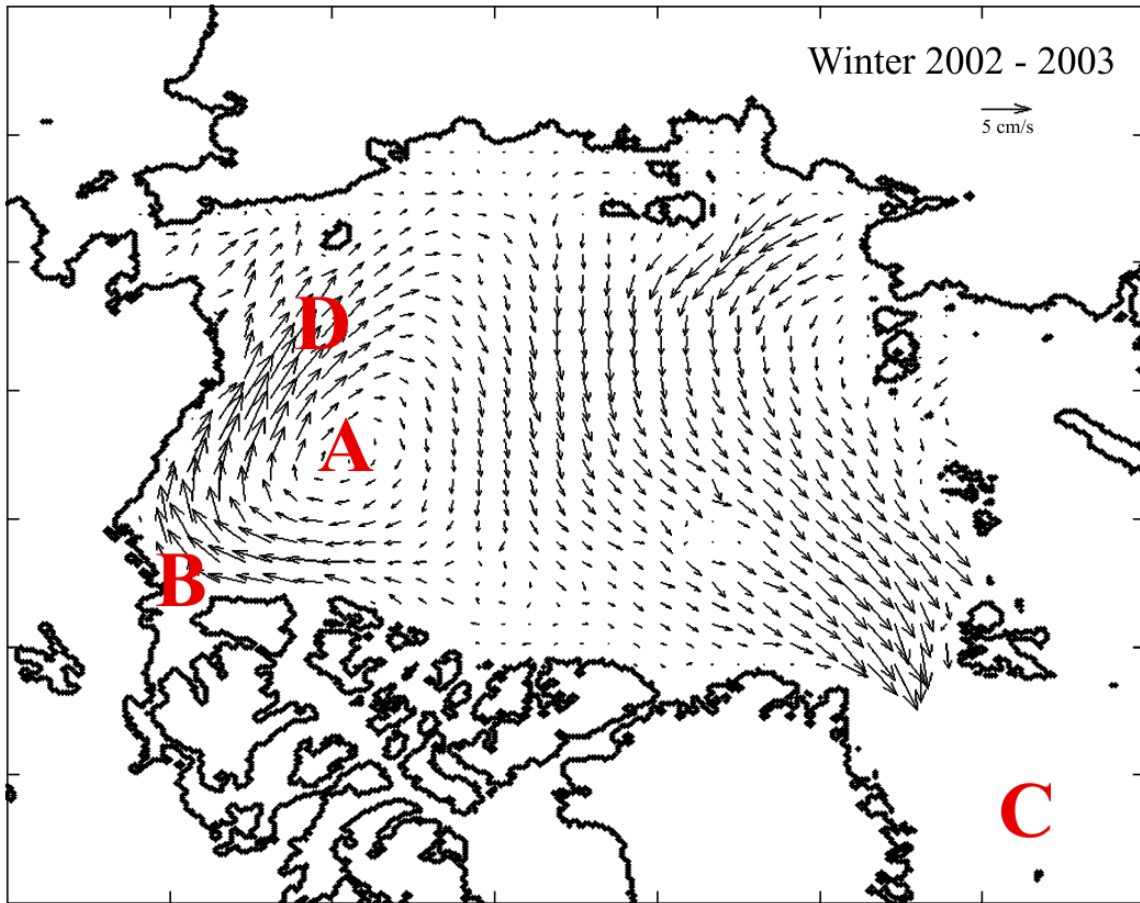
### Dew Point from Dry and Wet Bulb



- (a) (1 point) What is the dew point at the surface?
- (b) (1 point) The local atmosphere is:
- A. Absolutely stable
  - B. Absolutely unstable
  - C. Conditionally unstable
- (c) (3 points) At what elevation, in meters, will the cloud base be? Show work for all calculations.

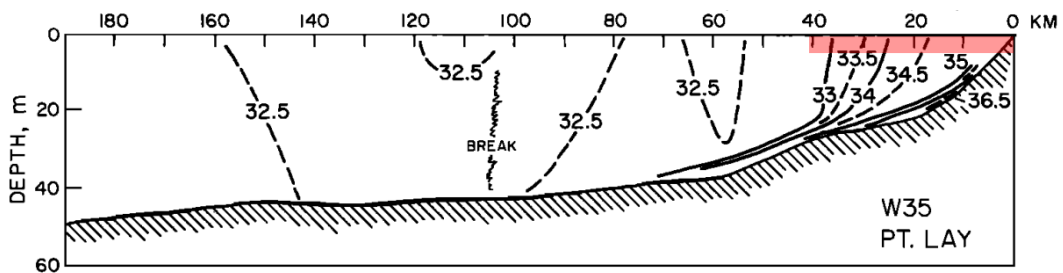
## Problem 4

Question	1	2	3	4	Total
Points	2	4	4	4	14 (23%)



**Figure 5:** Arctic Ocean mean sea-ice motion map of the 2002-2003 winter season. Figure adapted from Zhao and Liu (2007).

- (2 points) Letter A denotes the center of the Beaufort Gyre. Classify the Beaufort Gyre as either anticyclonic or cyclonic and describe the relative sea surface heights at A and B (i.e., higher or lower).



**Figure 6:** Salinity profile at an Arctic polynya (colored red). The bottom topography is denoted with the shaded portion. Figure adapted from Aagaard et al. (1985)

2. Water masses in the Arctic are largely altered through sea ice formation.
- (a) (1 point) Briefly describe one way by which sea ice formation may alter the temperature or salinity of a water mass.
  - (b) (3 points) Letter B marks the location of the Cape Bathurst Polynya. Polynyas are areas of coastal ocean that are semi-permanently exposed to air (i.e., no ice cover) and function as zones of active ice formation. Describe the vertical movement of water at a polynya, and justify why it may move as such.
3. Circulation in the Arctic Ocean may be simplified as a combination of Ekman (i.e., wind driven) and geostrophic components.

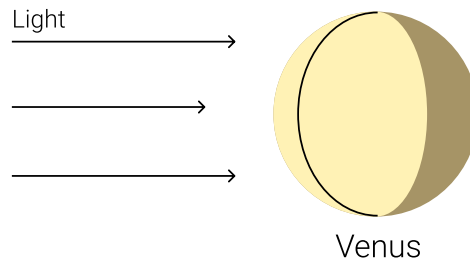
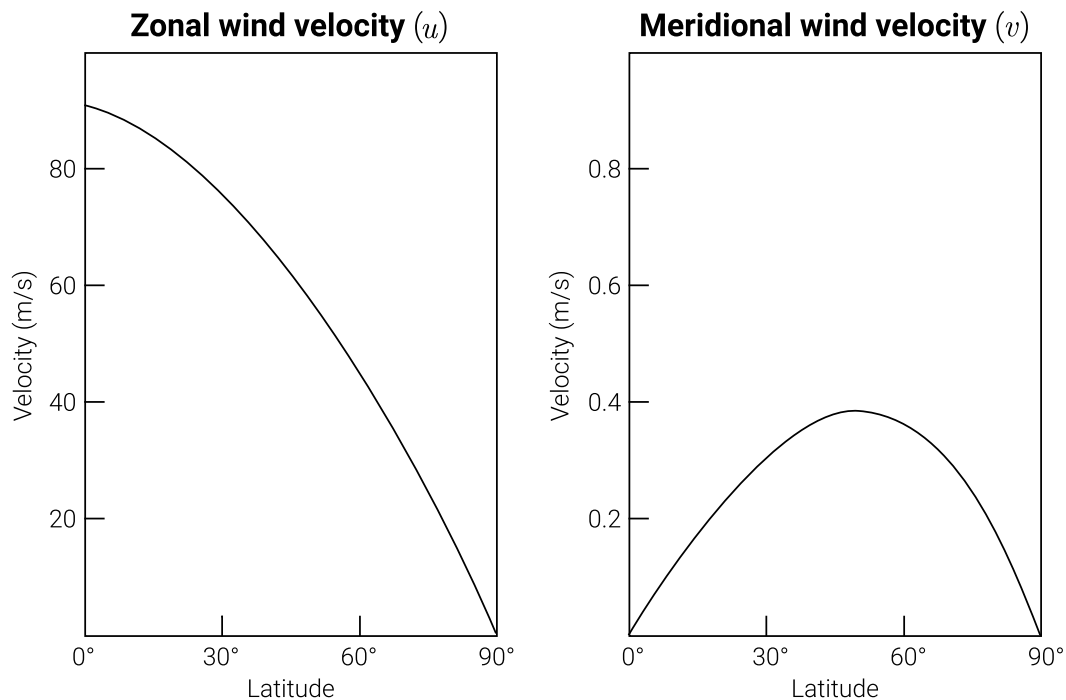
$$v_{tot} = v_{Ek} + v_{geo} \quad (1)$$

- (a) (1 point) Which two of the following forces must be balanced for geostrophy? (Select two)
    - A. Pressure gradient force
    - B. Coriolis force
    - C. Centripetal force
    - D. Centrifugal force
    - E. Buoyant force
  - (b) (3 points) Would the ratio of Ekman to geostrophic velocity  $v_{Ek}/v_{geo}$  be greater at (the surface of) D or C? Justify your answer.
4. (4 points) The Arctic is one of the most rapidly evolving regions on Earth due to the effects of anthropogenic climate change. An important feedback loop in the Arctic is the sea-ice albedo feedback. Describe its mechanism and characterize it as either a positive or negative feedback.

## Problem 5

Question	1	2	3	Total
Points	3	6	2	11 (18%)

- (3 points) Venus has an orbital period of 224.65 days. On Venus, an apparent solar day (i.e., the amount of time it takes for the sun to pass over the same spot in the sky) is 116.75 earth days. Calculate the rotation period of Venus, to the nearest day. Note that Venus spins in retrograde, meaning that its rotation is in the opposite direction of its revolution about the Sun. Show work for all calculations.
- An idealized atmospheric model of Venus gives the following zonal (i.e., in the east-west direction) and meridional (i.e., in the north-south direction) wind velocity profiles. The profiles are taken along the meridian shown in the model below and are averaged across all heights.



Provide a brief explanation to account for the following observations:

- (2 points) Meridional velocity is strictly positive, meaning there is only one atmospheric convection cell, contrary to the three on Earth.
- (2 points) Zonal velocity is two orders of magnitude greater than meridional velocity.
- (2 points) Zonal wind velocity is the greatest at the equator and weakest at the poles.



3. (2 points) A surface map of Venus is shown above. Notice the lack of craters, despite Venus lacking an active tectonic cycle. Propose an explanation for the relative lack of impact craters on Venus.

**END OF SECTION II**