a place of mind
THE UNIVERSITY OF BRITISH COLUMBIA

FINAL EXAMINATION: DECEMBER 2021

Course number: **ATSC 201** Section number: 101
Course name: Meteorology of Storms. Duration: 2.5 hours

Candidate name _____

Student number _____Candidate signature _____

Special instructions: Open books, notes, laptops, iPads, and calculator. No other electronics (cell phones, ear phones). Indicate your name, student ID, Test Form (All exams this term are Test Form **A**), and all your answers on the Bubble sheet. Each question has only one best answer. Don't leave any questions unanswered (if you don't know the answer, then guess). Good luck!

Instructor name: Roland Stull

This examination consists of 6 pages (including this cover sheet & bubble sheet). Check to ensure that it is complete. Students ARE allowed to separate all the exam sheets from each other. Students must turn in ALL pages of this exam. The bubble sheet will be marked by computer for the multiple-choice questions, and other questions involving maps or diagrams will be marked by hand. Please do NOT re-staple the bubble sheet to the exam packet.

Rules governing formal examinations

1. Each examination candidate must be prepared to produce, upon the request of the invigilator or examiner, his or her UBC card for identification.

2. Examination candidates are not permitted to ask questions of the examiners or invigilators, except in cases of supposed errors or ambiguities in examination questions, illegible or missing material, or the like.

3. No examination candidate shall be permitted to enter the examination room after the expiration of one-half hour from the scheduled starting time, or to leave during the first half hour of the examination. Should the examination run forty-five (45) minutes or less, no examination candidate shall be permitted to enter the examination room once the examination has begun.

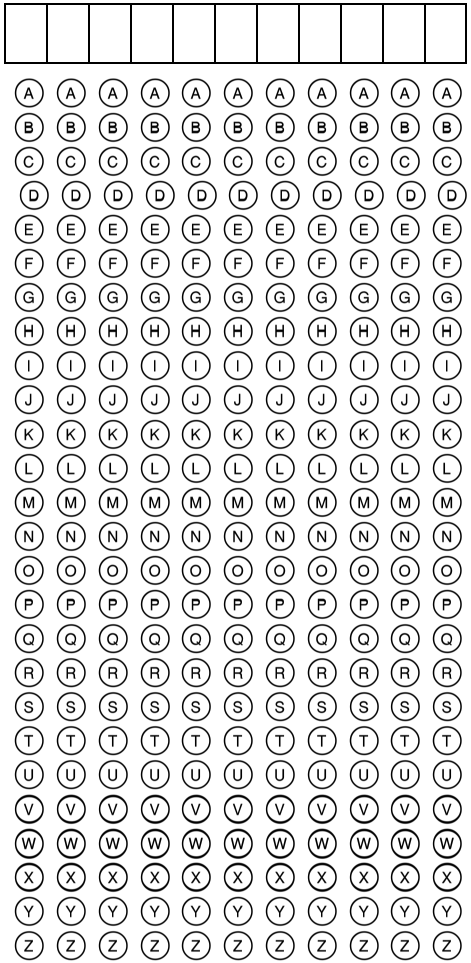
4. Examination candidates must conduct themselves honestly and in accordance with established rules for a given examination, which will be articulated by the examiner or invigilator at the start of the examination. Should dishonest behaviour be observed by the examiner(s) or invigilator(s), pleas of accident or forgetfulness shall not be received.

5. Examination candidates suspected of any of the following, or any other similar practices, may be immediately dismissed from the examination by the examiner/invigilator, and may be subject to disciplinary action:
   i. speaking or communicating with other examination candidates, unless otherwise authorized;
   ii. purposely exposing written papers to the view of other examination candidates or imaging devices;
   iii. purposely viewing the written papers of other examination candidates;
   iv. using or having visible at the place of writing any books, papers or other memory aid devices other than those listed above under Special Instructions or authorized by the examiner(s);
   v. using or operating electronic devices including but not limited to telephones, calculators, computers, or similar devices other than those authorized by the examiner(s)—(electronic devices other than those authorized by the examiner(s) must be completely powered down if present at the place of writing);
   vi. copying, scanning, or photographing any parts of the exam to take or transmit outside of the exam room;
   vii. use of the internet and use of search engines such as Google.

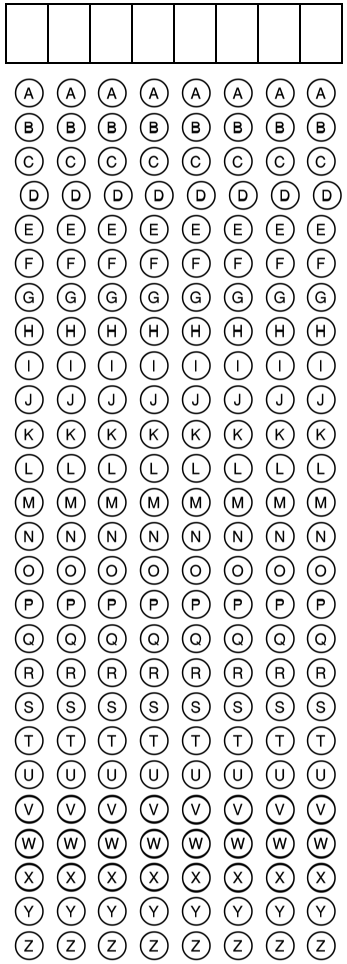
6. Examination candidates must not destroy or damage any examination material, must hand in all examination papers, and must not take any examination material from the exam room without permission of the examiner or invigilator.

7. Examination candidates must follow any additional examination rules or directions communicated by the examiner(s) or invigilator(s).

LAST NAME



FIRST NAME



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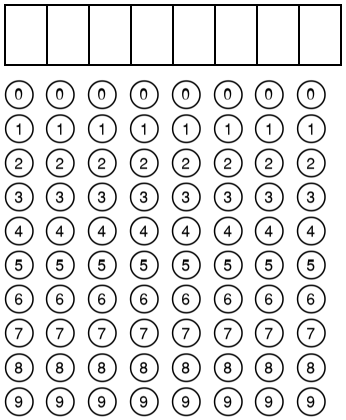


TEST FORM

ATSC 201 section 101
December 2021
Final Exam

1	A	B	C	D	E	36	A	B	C	D	E	71	A	B	C	D	E
2	A	B	C	D	E	37	A	B	C	D	E	72	A	B	C	D	E
3	A	B	C	D	E	38	A	B	C	D	E	73	A	B	C	D	E
4	A	B	C	D	E	39	A	B	C	D	E	74	A	B	C	D	E
5	A	B	C	D	E	40	A	B	C	D	E	75	A	B	C	D	E
6	A	B	C	D	E	41	A	B	C	D	E	76	A	B	C	D	E
7	A	B	C	D	E	42	A	B	C	D	E	77	A	B	C	D	E
8	A	B	C	D	E	43	A	B	C	D	E	78	A	B	C	D	E
9	A	B	C	D	E	44	A	B	C	D	E	79	A	B	C	D	E
10	A	B	C	D	E	45	A	B	C	D	E	80	A	B	C	D	E
11	A	B	C	D	E	46	A	B	C	D	E	81	A	B	C	D	E
12	A	B	C	D	E	47	A	B	C	D	E	82	A	B	C	D	E
13	A	B	C	D	E	48	A	B	C	D	E	83	A	B	C	D	E
14	A	B	C	D	E	49	A	B	C	D	E	84	A	B	C	D	E
15	A	B	C	D	E	50	A	B	C	D	E	85	A	B	C	D	E
16	A	B	C	D	E	51	A	B	C	D	E	86	A	B	C	D	E
17	A	B	C	D	E	52	A	B	C	D	E	87	A	B	C	D	E
18	A	B	C	D	E	53	A	B	C	D	E	88	A	B	C	D	E
19	A	B	C	D	E	54	A	B	C	D	E	89	A	B	C	D	E
20	A	B	C	D	E	55	A	B	C	D	E	90	A	B	C	D	E
21	A	B	C	D	E	56	A	B	C	D	E	91	A	B	C	D	E
22	A	B	C	D	E	57	A	B	C	D	E	92	A	B	C	D	E
23	A	B	C	D	E	58	A	B	C	D	E	93	A	B	C	D	E
24	A	B	C	D	E	59	A	B	C	D	E	94	A	B	C	D	E
25	A	B	C	D	E	60	A	B	C	D	E	95	A	B	C	D	E
26	A	B	C	D	E	61	A	B	C	D	E	96	A	B	C	D	E
27	A	B	C	D	E	62	A	B	C	D	E	97	A	B	C	D	E
28	A	B	C	D	E	63	A	B	C	D	E	98	A	B	C	D	E
29	A	B	C	D	E	64	A	B	C	D	E	99	A	B	C	D	E
30	A	B	C	D	E	65	A	B	C	D	E	100	A	B	C	D	E
31	A	B	C	D	E	66	A	B	C	D	E						
32	A	B	C	D	E	67	A	B	C	D	E						
33	A	B	C	D	E	68	A	B	C	D	E						
34	A	B	C	D	E	69	A	B	C	D	E						
35	A	B	C	D	E	70	A	B	C	D	E						

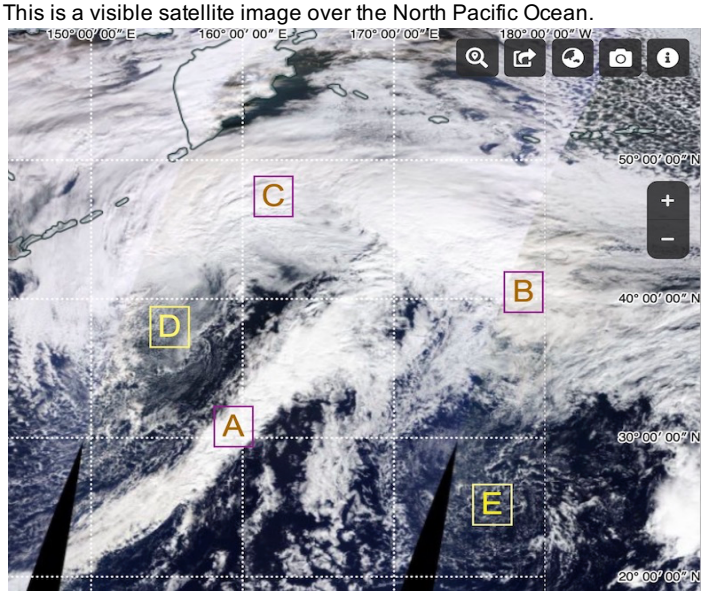
ATSC 201 . Fall 2021
Prof. Roland Stull

Final Exam
Open books, notes, laptop, ipad, calculator.

Name: _____

Student Number: _____

Put your answers on the "bubble sheet", unless otherwise instructed in the question. Turn in ALL question and answer sheets.
120 points total, or roughly 1 point per minute. The bubble sheet will be marked by computer. Other sheets will be marked by hand.

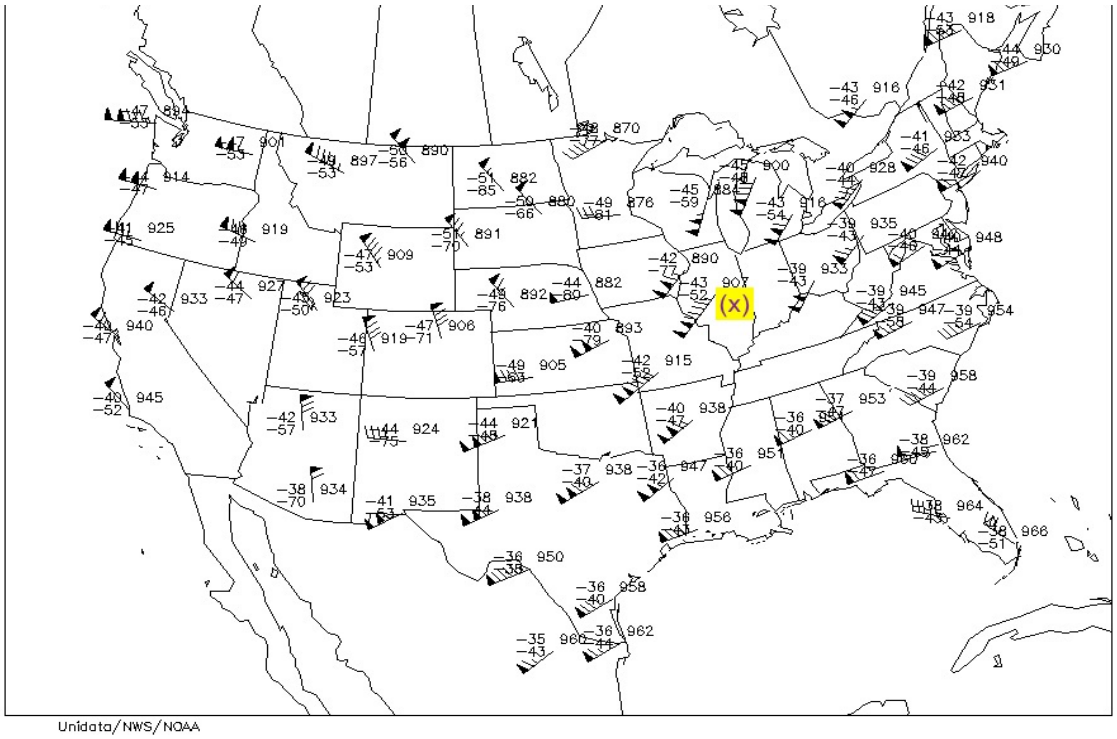
Exercise	points	
1)	2	The clouds above UBC today at the start of the exam were A. cirrus, cirrostratus, or cirrocumulus B. altostratus or altocumulus C. stratus or nimbostratus D. cumulus (of any size) or cumulonimbus E. clear, stratocumulus, or other
2)	5	You observe the following weather: Surface winds from the northwest, clear skies, pressure rising. Based on typical idealized Northern Hemisphere midlatitude cyclone and frontal configurations, your forecast for the next few hours is A. warm front approaching. Increasing stratiform clouds with chance of drizzle. B. warm front has just passed. Clearing skies and warmer temperatures. C. cold front approaching. Thunderstorms approaching with heavy rain showers and possible severe weather. D. cold front has just passed. Decreasing temperatures and winds, with scattered cumulus clouds. E. occluded front is passing now. Thunderstorm showers embedded in widesptread drizzle from nimbostratus.
3)	2	Which phenomenon is a vertically direct global circulation that is associated with the ITCZ, subtropical jet, and trade winds? A. barotropic instability B. polar front C. Supercell D. Ferrel cell E. Hadley cell
4)	9	Given a north-south temperature gradient of $\Delta T/\Delta y$ = -14 °C / 200 km in the Northern Hemisphere where $f_c = 10^{-4}$ s^{-1}. You would expect the geostrophic wind Ug to _____ across a vertical height of Δz= 1 km Assume dry air with average temperature of 0 °C A. increase about 50 m/s B. increase about 25 m/s C. increase about 12.5 m/s D. decrease about 12.5 m/s E. decrease about 25 m/s
5)	2	This is a visible satellite image over the North Pacific Ocean.  Based on this satellite image, which statement is TRUE? A. The warm front is at A. B. The cold front is at B. C. The occluded front is at C. D. The anticyclone is at D. E. The cyclone is at E.
6)	3	Using the 3 main satellite channels, you observed the following: Visible: bright white. IR: bright white. Water Vapour: bright white. The most likely phenomenon that you are observing is: A. thunderstorm B. cirrostratus C. altostratus D. low stratus or fog E. snow-topped mountains
7)	3	Which statement is FALSE? A. Near the earth's surface, thermal highs tend to form over warm continents. B. Colder air can hold less water vapour at saturation than warmer air. C. Away from the equator, winds tend towards geostrophy. D. Saturated air cools less rapidly with increasing height than unsaturated air. E. Pressure gradient force does not depend on wind speed.

8) 10 The following upper-air weather map is for a 30 kPa isobaric surface.
Winds barbs in knots are shown at each rawinsonde sounding station.
For this upper-air map, use the following station plot model:

T (°C)		H (tens of meters)
	(station)	
Td (°C)		

For example: H value of 870 corresponds to 8.7 km geopotential height.

Analyze (i.e., draw) the height contours on this map for H = 8.8, 9.0, 9.2, 9.4, and 9.6 km
We will grade the quality of your map analysis.



9) 2 Based on your analysis of height contours, and the relationship between wind directions and height contours, you anticipate the winds at location (x) on the map above will be nearly equal to the theoretical _____ wind speed.
A) boundary layer B) boundary layer gradient C) cyclostrophic
D) geostrophic E) gradient

10) 2 The wind speed plotted on the map above at location (x) is approximately ___ knots.
A. 13.5 B. 45 C. 75 D. 100 E. 145

11) 5 If the pressure at sea level in the eye of a typhoon is 91 kPa,
Then what is the Saffir-Simpson category for the typhoon intensity?
A. Category 1 B. Category 2 C. Category 3 D. Category 4 E. Category 5

12) 3 Thunderstorms are usually associated with what type(s) of fronts?
A. only cold fronts B. only warm fronts C. both warm and cold fronts
D. only occluded fronts E. both occluded and cold fronts

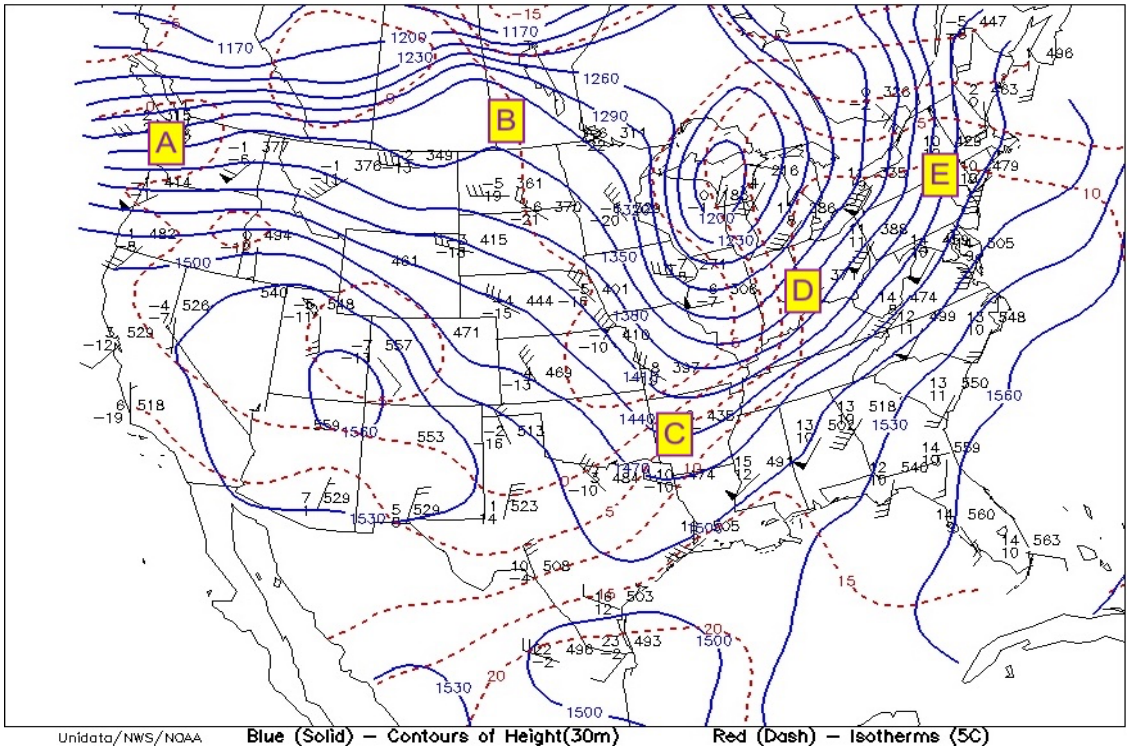
13) 3 Which statement is TRUE?
A. Hurricanes that move across the equator change their rotation direction.
B. The warm core of the hurricane creates relatively high pressure in the eye at storm top.
C. Hurricanes need a sea surface temperature of at least 20°C.
D. Tropical cyclones in the North-east Pacific Ocean are called typhoons.
E. The main cause of death associated with tropical cyclones, hurricanes and typhoons is the strong winds near the eyewall, which cause flying debris.

14) 3 Regarding the evolution of extratropical cyclones, the winds in the boundary layer tend to cause
A. cyclolysis B. cyclostrophic winds C. cyclogenesis
D. anticyclogenesis E. jet streaks

This next upper-air map shows geopotential height contours of the 85 kPa isobaric surface.
Namely, it is the 85 kPa Height map.

Height contours are already drawn as solid blue lines, in meters above sea level.
For example, a value of 1530 corresponds to H = 1.53 km above sea level.

Isotherms are already drawn as dashed red lines, in degrees C.
Use this map to answer the next 3 questions.



15) 2 At which location (A, B, C, D, or E) is a trough.

16) 4 At which location (A, B, C, D, or E) is a warm front.

17) 2 At which location (A, B, C, D, or E) is a ridge.

18) 4 Rossby waves
A. are long-wavelength ocean waves known as swell
B. are caused by barotropic and baroclinic instabilities of the jet stream
C. are vertical oscillations also known as mountain waves that occur in statically stable air.
D. usually have positive values of intrinsic phase velocity
E. are interesting phenomena that are not relevant for weather forecasting.

19) 3 Why do mid-latitude cyclones at the earth's surface often form east of troughs in the upper-air jet stream?
A. because of warm air west of the trough causes the thickness of the air column to increase.
B. because the jet stream is caused by baroclinicity associated with the north-south temperature gradient.
C. because of the time lag for low pressure aloft to propagate downward toward the earth's surface.
D. because upper-air divergence in the jet removes air molecules from the air column
E. because they form under the low pressure of the trough before being advected to the east.

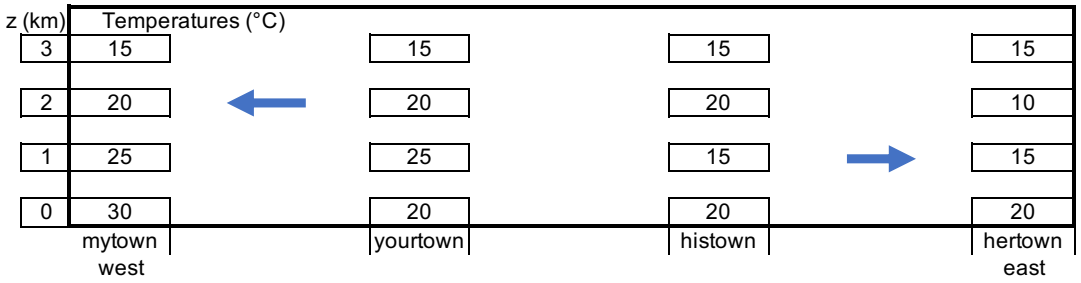
20) 6 Suppose that the jet stream of tropospheric air is blowing directly from west to east over a plateau of constant height. The thickness of the troposphere in this region is 8 km. Then, the air reaches the edge of the plateau, after which the thickness of the troposphere increases to 10 km.
Because of this change in thickness, the wind will
A. turn counterclockwise due conservation of relative vorticity.
B. turn clockwise due to conservation of relative vorticity.
C. continue moving straight from west to east
D. turn clockwise due to conservation of potential vorticity.
E. turn counterclockwise due to conservation of potential vorticity.

Final Exam
Open books, notes, laptop, ipad, calculator.

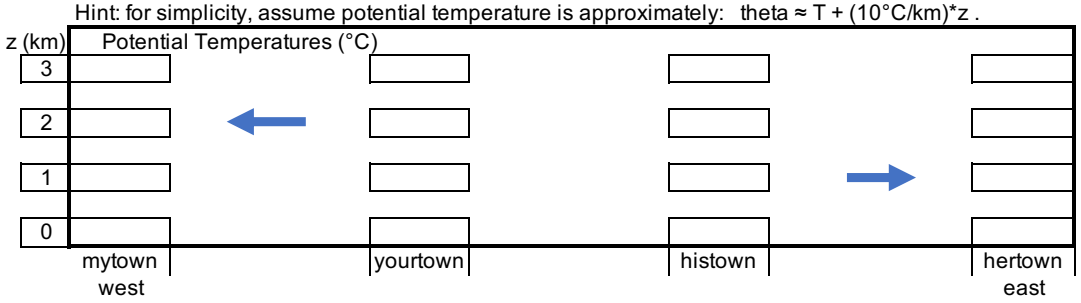
Name: _____

Student Number: _____

21) 15 Given the following vertical cross-section of air temperatures observed at the indicated heights, and two wind vectors as drawn.



First, convert these temperatures to potential temperatures, and write these in the boxes provided below.
Hint: for simplicity, assume potential temperature is approximately: theta ≈ T + (10°C/km)*z .



Then, analyze that vertical cross-section by drawing isentropes (lines of equal potential temperature) for theta values of 20, 25, 30, 35, 40, 45 (°C). Draw these on top of the theta numbers above, and lightly shade the frontal zone. This question will be hand marked-based on your analysis of the isentropes and front.

22) 3 For the previous analysis that you made, what type of front is it? A. cold katafront
B. cold anafront C. stationary front D. warm anafront E. warm katafront

23) 12 Suppose jet-stream air is at a latitude where the beta parameter is 1.5×10^{-11} $m^{-1}\ s^{-1}$.
If the background jetstream wind speed is 50 m/s toward the East,
and the wavelength of a Rossby wave is 7000 km,
Then how fast will the troughs in the Rossby wave move toward the East relative to the earth's surface for a wave caused by barotropic instability? Convert your answer to km / day.
A. -1609 B. -18.6 C. 31.4 D. 2711 E. 4320

24) 10 Suppose an atmospheric river of speed 5 m/s is advecting humid air from Hawaii towards the mountains near Abbottsford, BC. This atmospheric river gains moisture as it flows over the Pacific Ocean, such that by the time this air reaches the BC coast, it is saturated with a temperature of 10 °C
Next, this air is forced to rise from z = 0 to z = 2000 m over the nearby mountains.
As water vapour condenses, assume that **half** of the liquid water falls out as rain into your rain gauge.
Approximately how much water (as depth in a rain gauge) would accumulate over 2 days of rain?
A. 1,200 m B. 2.4 m C. 2.0 m D. 1.6 m E. 1.2 m
For simplicity, assume that the rainfall rate RR as measured in your rain gauge is given by

$$RR = a * M * r_L$$

where M is wind speed, r_L is liquid water mixing ratio, a = 0.001 $kg_{air} / kg_{liquid.water}$.
and where RR is change of depth (m) of water in the rain gauge vs. time (s). Hints, do the following in order:
a. Use a thermo diagram from the textbook to estimate the initial total water mixing ratio for the humid air just before it rises.
b. Use a thermo diagram to estimate the final water vapor mixing ratio.
c. Assume the difference between initial and final mixing ratios gives the liquid water mixing ratio , r_L, which **half** of which we assume falls as precipitation.

25) 5 If the earth didn't rotate about its axis, then
A. Differential heating would not exist.
B. The Earth's poles would be warmer than the equator.
C. Le Chatelier's principle suggests that the subtropical jet would be displaced and would be strongest at the north and south poles.
D. Coriolis force would be zero, so atmospheric motions would not exist.
--end of exam -- E. Warm air would rise on the sunlight side of the earth and cool air would sink on the shaded side.