A12f) (3.5 marks)

Given the pressure gradient magnitude (kPa/1000km) below, find geostrophic wind speed for a location having fc = 1.1x10^-4 /s and rho = 0.8kg/m^3.
f) 6

Given:	fc =	1.10E-04	/s
	rho =	0.8	kg/m^3
	delta_P / delta_d =	6	kPa/1000km

Find:	G =	?	m /s
	Geostrophic wind		

Using equation 10.28:

$$G = \left| \frac{1}{\rho \cdot f_c} \cdot \frac{\Delta P}{\Delta d} \right|$$

Convert ΔP / Δd from kPa/1000km to Pa/m:
The 'kilo' (x1000) on top and bottom can cancel each other out, so
kPa / 1000km = Pa / 1000m. To get this into Pa / m, divide by 1000.

ΔP / Δd = 0.006 Pa / m

G = 68.18 m/s

Check: Units ok. Physics ok.

Discussion: Note that G is proportional to the PGF. When Δd (spacing between isobars) is smaller, PGF is larger and so is G.

A14f) (3 marks)

At the radius (km) given below from a low-pressure center, find the gradient wind speed given a geostrophic wind of 8 m/s and given fc = 1.1x10^-4 /s.
f) 1000.

Given:	R =	1000	km
	G =	8	m/s
	fc =	1.10E-04	/s

Find:	Mtan =	?	m/s

Using eq. 10.34a:

$$M_{tan} = 0.5 \cdot f_c \cdot R \cdot \left[-1 + \sqrt{1 + \frac{4 \cdot G}{f_c \cdot R}} \right]$$

Convert R(km) into R(m):

R (m) = 1000000

Mtan =	7.49	m/s

Check: Units ok. Physics ok.

Discussion: Gradient wind speed around a low is slower than the geostrophic wind because of the imbalance between the PGF and the Coriolis force caused by the curvature of the flow.

Chapter 11

A14f)
(3.5 marks)

> A14. Find the relative vorticity (s–1) for the change of (U , V) wind speed (m s–1), across distances of Δx = 300 km and Δy = 600 km respectively given below.
> f) 20, 50

Given:	ΔU =	20	m/s
	ΔV =	50	m/s
	Δx =	300	km
	Δy =	600	km

Find: ζr = ? /s

Use eq. 11.20:

$$\zeta_r = \frac{\Delta V}{\Delta x} - \frac{\Delta U}{\Delta y}$$

Convert Δx(km) and Δy(km) into Δx(m) and Δy(m):

Δx (m) = 300000 m

Δy (m) = 600000 m

ζr =	0.000133333	/s

Check: Units ok. Physics ok.

Discussion: Positive sign due to cyclonic motion

A17f)
(4 marks)

If the relative vorticity is 5x10^-5/s, find the absolute vorticity at the following latitude: f) 65 deg.

Given:	ζr =	5.00E-05	/s
	ϕ =	65	deg
Find:	ζa =	?	/s

Use eq. 11.23:

$$\zeta_a = \zeta_r + f_c$$

where fc = 2*Ω*sinϕ:

2Ω =	1.46E-04	/s

fc = 0.000132140 /s

ζa = 1.82E-04 /s

Check: Units ok. Physics ok.

Discussion: Fc increases with latitude and hence, absolute vorticity will be a maximum at the north pole. The 65th parallel passes through Greenland, and is almost in the Arctic Circle.

A18f)
(3.5 marks)

If absolute vorticity is 5x10^-5 /s, find the potential vorticity (/m*s) for a layer of thickness (km) of: f) 3

Given:	ζa =	5.00E-05	/s
	Δz =	3	km
Find:	ζp =	?	/(m*s)

Use eq. 11.24:

$$\zeta_p = \frac{\zeta_r + f_c}{\Delta z} = \text{constant}$$

where ζr + fc = ζa from eq. 11.23 or A17e.

Convert Δz(km) into Δz(m):

Δz (m) =	3000

ζp = 1.67E-08 /(m*s)

Check: Units ok. Physics ok.

Discussion: The potential vorticity is a useful definition in determining how a column of air would respond to stretching in order to conserve its potential vorticity in the absence of turbulent drag and heating. This reasoning is thought to influence storm development in the lee of the Rocky Mountains.

A19f)
(6 marks)

The potential vorticity is 1x10^-8 /(m*s) for a 10 km thick layer of air at latitude 48 degN. What is the change of relative vorticity (/s) if the thickness (km) of the rotating air changes to: f) 7?

Given:	ζp =	1.00E-08	/(m*s)
	Δzi =	10	km
	Δzf=	7	km
	ϕ =	48	deg

Find: Δζr = ? /s

Use eq. 11.24:

$$\zeta_p = \frac{\zeta_r + f_c}{\Delta z} = \text{constant}$$

where fc = 2*Ω*sinϕ:

2Ω =	1.46E-04 /s

fc = 1.08E-04 /s

Convert Δzi(km) and Δzf(km) to Δzi(m) and Δzf(m):

Δzi (m) =	10000
Δzf (m) =	7000

ζri = -8.50E-06 /s

Since we know ζp is constant, we can calculate new ζr with new Δz:

ζrf = -3.85E-05 /s

Therefore the change in relative vorticity is:

$\Delta\zeta r$ =	**$\zeta rf - \zeta ri$ =**	**-3.00E-05 /s**

Check: Units ok. Physics ok.

Discussion: For a fixed latitude, the planetary vorticity will not change. When the thickness decreases from 10km to 7km, the result is the generation of negative relative vorticity, causing the wind to spin faster in the clockwise direction (or slower in the counter-clockwise direction).

Chapter 14

A18b)
(2 marks)

Solution: See attached figure. Ch14_18b
z: 0,1,2,3,4,5,6 (km)
b. (100,5),(120,10),(160,15),(220,25),(240,30),(250,33),(250,33)

Check: Curve looks reasonable, similar to Fig. 14.62b).
Discussion: The hodograph shows a view of the change in wind speed and direction with altitude. The sounding data given is showing an increase in the winds with height. These conditions favour multicell thunderstorms.

A23)
(3 marks)

Graphically, using your hodograph plot from exercise A18, plot the 0 to 6 km mean shear vector (m/s).

Solution: See attached figure. Vector plotted under wind vectors

Mean shear direction = imaginary line connecting point 0 to point 6

Mean shear magnitude (roughly) 5.35714286

Check: Looks reasonable compared to textbook vectors
Discussion: The hodograph allows a very easy way to do the vector math to find the mean shear vector, even if the surface wind is not 0 m/s.

A28)
(3.5 marks)

Graphically, using your hodograph plot from exercise A18, find the mean environmental wind direction (deg) and speed (m/s), for normal storm motion.

Solution: See attached hodograph. X

Method 1) Approximate by finding center of mass.
OR
Method 2) Vector sum method

U=	-12.3364829	m/s	V=	-11.159421	m/s
dir (deg)	222.1320812				
dir =	**222.13**	deg			
speed (m/s)	16.63494772				
speed =	**16.63 m/s**				

Check: Looks to be near center of mass
Discussion: For a normal thunderstorm, under these environmental wind conditions, the general movement of the storm will move from the SW at a speed of 16.63 m/s. This speed corresponds to roughly 60 km in one hour.

A30)
(6 marks)

Given the hodograph shape from exercise A18, indicate whether right or left-moving supercells would dominate. Also, starting with the "normal storm

moving supercells would dominate. Also, starting with the "normal storm
motion" from exercise A28 (based on hodograph from A18), use Internal Dynamics method on your hodograph to graphically estimate the movement (i.e. direction and speed) of Right-and Left-moving supercell thunderstorms.

<u>Internal Dynamics method:</u>

1) Approximate the 0.25 to 5.75 km layer shear vector using the 0 to 6 km mean shear vector
2) Draw line perpendicular to mean shear vector
3) R and L are long this line, 7.5 m/s from the center of mass
4) For right-moving supercell thunderstorms, estimated movement:

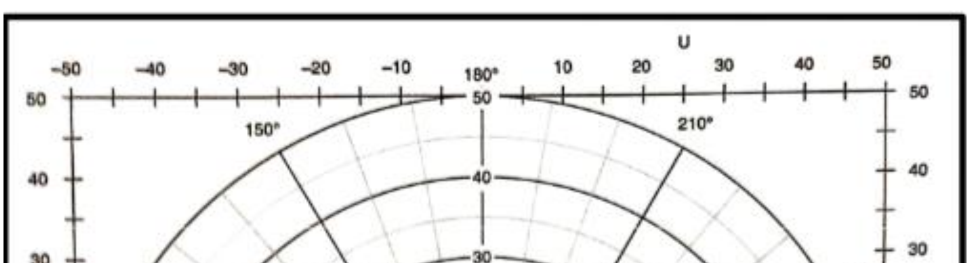
direction =	**255 deg**
speed =	**14 m/s**

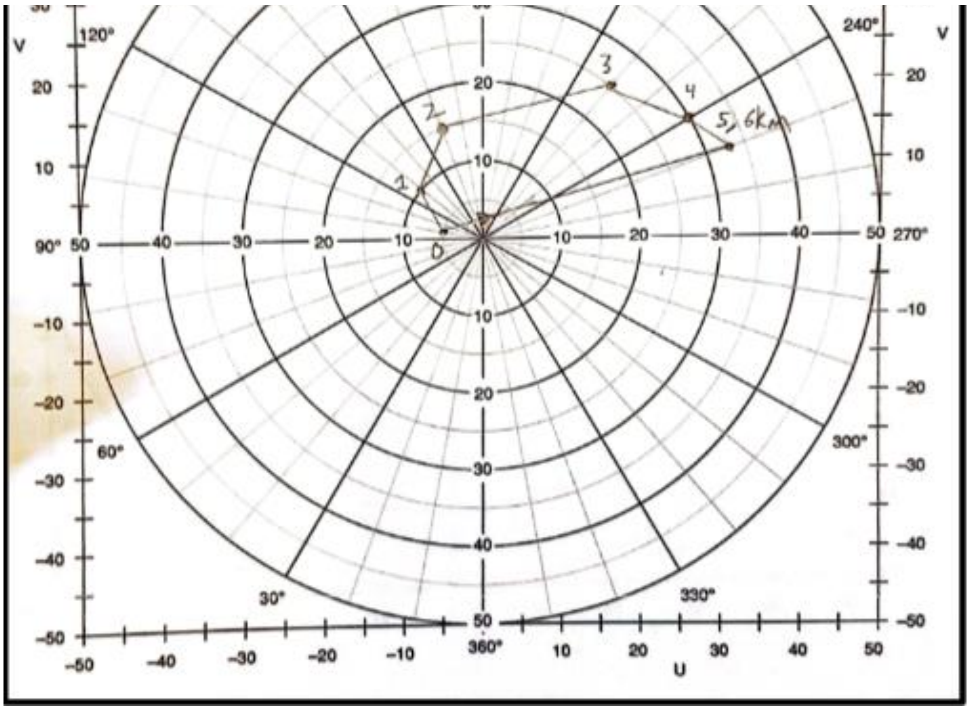
For left-moving supercell thunderstorms, estimated movement:

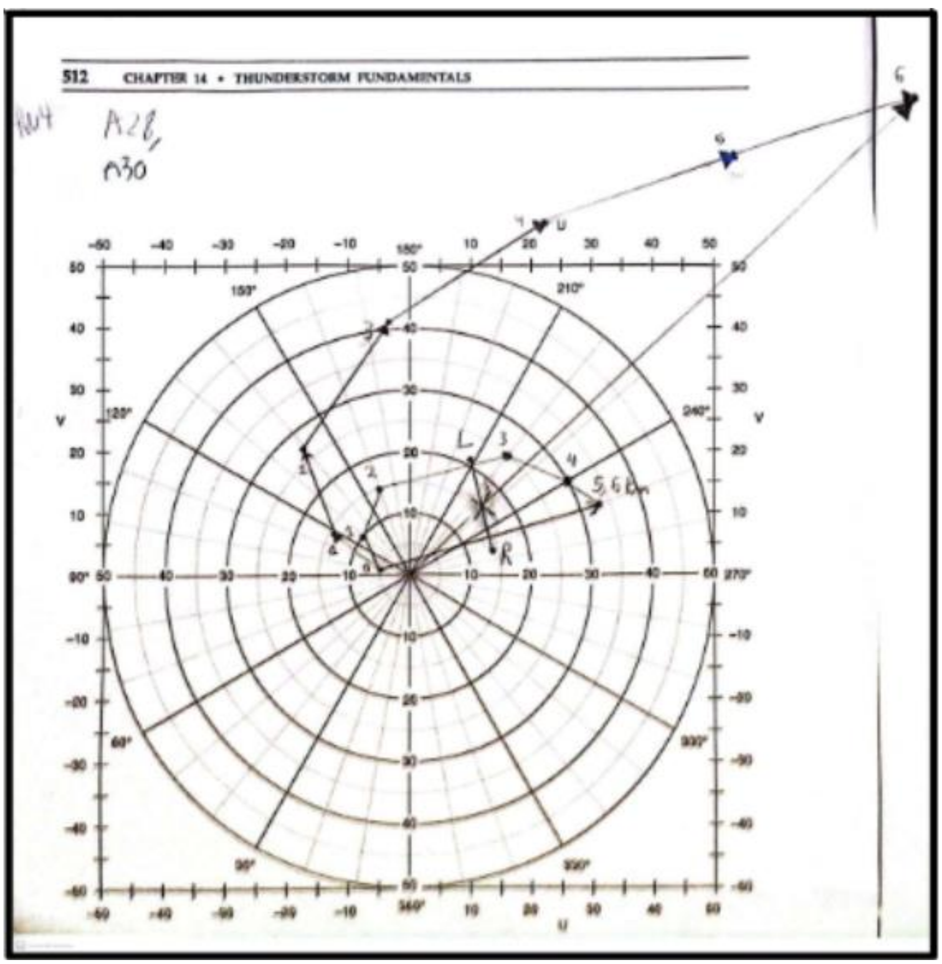
direction =	**210 deg**
speed =	**20 m/s**

Given the hodograph shape, the right moving super cells would dominate.
(See Fig. 14.62)

Check: L and R points look similar to textbook hodographs
Discussion: Wind shear is only one of the main ingredients in the formation of a thunderstorm; others include the amount of available moisture, instability, and a trigger mechanism that will create uplift.




120°
240°
V
U
90°
270°
60°
300°
30°
330°
360°
0
1
2
3
4
5, 6km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A28,
A30
180°
150°
210°
120°
240°
90°
270°
60°
300°
30°
330°
360°
V
U
L
R
5,6km