HW 5 Answer Key

ATSC 201 Fall 2025
Total marks out of 40
Chapter 15: A1g, A3g, A26g, A27g, A29g, A33g, A36g

Chapter 15

A1g)
4.5 marks

If a thunderstorm cell rains for 0.5 h at the precipitation rate (mm h–1) below, calculate both the net latent heat released into the atmosphere, and the average warming rate within the

Given:	rr=		200	mm/h
	Δt =		0.5	h
Convert:				
	Δt =		1800	s
Find:				
	H=	?		J
	ΔT/Δt =	?		K/h

Use eq. 15.2 Hrr=a*RR

a= 694 Js-1m-2/(mm/h)

Hrr= 138800 Js-1m-2

H= Hrr*Δt = 249840000 Jm-2

Use eq. 15.3 ΔT/Δt = b*RR

b= 0.33 K/(mm of rain)

ΔT/Δt = 66 K/h

Check: Units ok. Physics ok.
Discussion: The total warming over the tropospheric depth is about 249 840 000 J/m^2 and the warming rate over the troposphere is 66 K/h which signifies that over half an hour the troposphere would have warmed by about than 33°C.

A3g)
2.5 marks

Graphically estimate the terminal fall velocity of hail of diameter (cm): g) 2.7

Given:

d= 2.7 cm

Find:

wt= ? m/s

Use Fig. 15.4

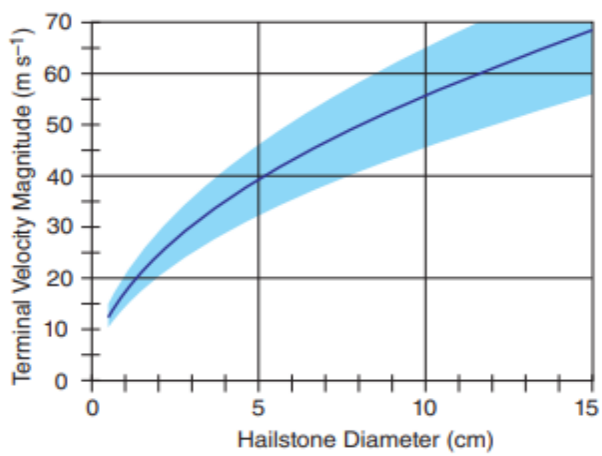

Figure 15.4
Hailstone fall-velocity magnitude relative to the air at pressure height of 50 kPa, assuming an air density of 0.69 kg m^{-3}.

Based on Fig. 15.4

wt=	30 m/s

Check: **units ok**

Discussion: A hailstone with a diameter of 2.7cm is about the size of a walnut, this hailstone can reach a terminal velocity of 30m/s which is equal to 90km/h which is almost as fast as a moving car on the highway.

A26g)
(2.5 marks)

How low below ambient 100 kPa pressure must the core pressure of a tornado be, in order to support max tangential winds (m s–1) of: g) 80

Given:	P0=	100	kPa
	Mtanmax=	80	m/s
	rho=	1	kg/m3
Find:	ΔP =	?	kPa

Use eqn. 15.44: ΔPmax = rho*(Mtanmax)^2

ΔP = 6400.00 Pa

ΔP = 6.40 kPa

Check: Units ok. Physics ok.

Discussion: According to the TORRO scale, this pressure difference would yield a moderately devastating (T6) tornado.

A27g)
13 marks

For a Rankine Combined Vortex model of a tornado, plot the pressure (kPa) and tangential wind speed (m/s) vs radial distance (m) out to 125m, for a tornado of core radius 25m and core pressure deficit (kPa) of: g) 0.7

Given: Ro = 25 m
ΔP (at core) = 0.7 kPa 700 Pa

Find: P (kPa) and Mtan (m/s) for R = 0 to 125 m

Inner region:

$$\frac{\Delta P}{\Delta P_{max}} = 1 - \frac{1}{2}\left(\frac{R}{R_o}\right)^2$$

It is evident

$$\frac{M_{tan}}{M_{tan\,max}} = \frac{R}{R_o}$$

First, we

ΔP = ΔPmax = 700 Pa

Outer region:

Outer Region ($R > R_o$):

$$\frac{M_{tan}}{M_{tan\,max}} = \frac{R_o}{R} \qquad \bullet(15.42)$$

$$\frac{\Delta P}{\Delta P_{max}} = \frac{1}{2}\left(\frac{R_o}{R}\right)^2 \qquad \bullet(15.43)$$

We can then use eqn 15.44 to calculate Mtanmax

$$\Delta P_{max} = \rho \cdot (M_{tan\,max})^2 \qquad \bullet(15.44)$$

where rho = 1 kg/m^3

Mtanmax = 26.46 m/s
(at R = Ro = 25m)

We can now calculate our Mtan values for our plot:
Use eqn. 15.40 for R < Ro:

Mtan = Mtanmax*(R/Ro)

Use eqn. 15. 42 for R > Ro:

$$\frac{M_{tan}}{M_{tan\,max}} = \frac{R_o}{R}$$

And our ΔP values:
Use eqn. 15.41 for R<Ro:

ΔP = ΔPmax*(1 - 0.5*(R/Ro)^2)

Use eqn. 15.43 for R>Ro:

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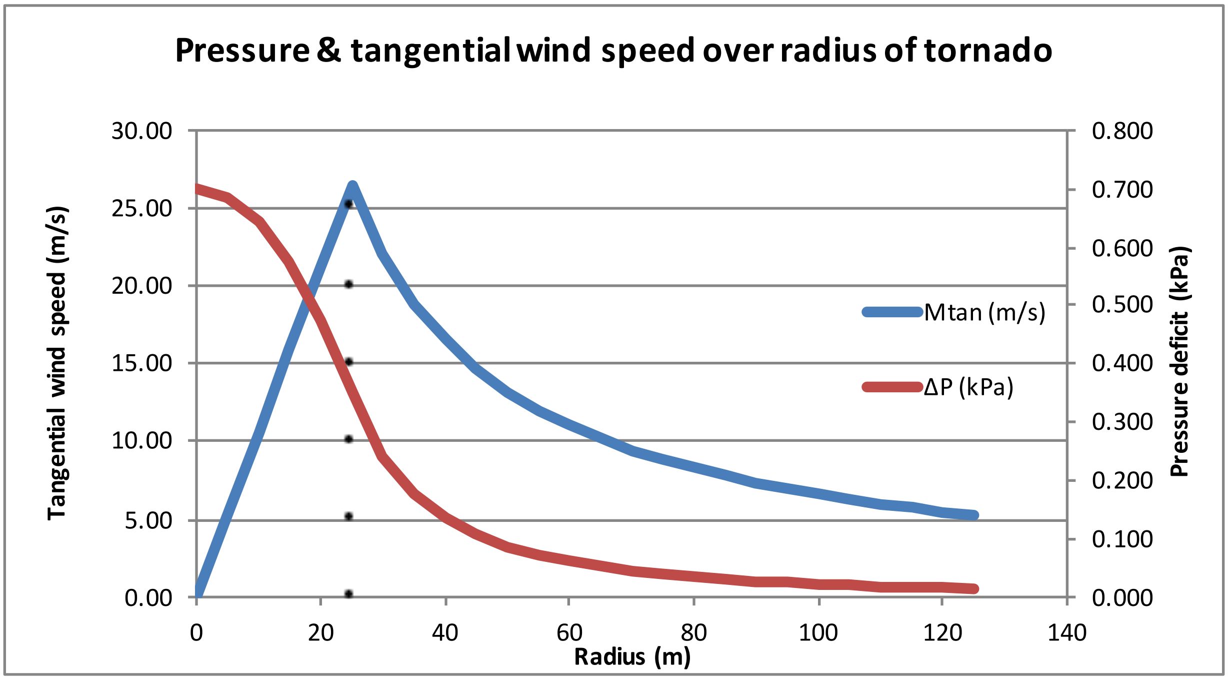
	R (m)	Mtan (m/s)	ΔP (Pa)	ΔP (kPa)
Core Region	0	**0.00**	700	**0.700**
	5	**5.29**	686	**0.686**
	10	**10.58**	644	**0.644**
	15	**15.87**	574	**0.574**
	20	**21.17**	476	**0.476**
	25	**26.46**	350	**0.350**
Outer Region	30	**22.05**	243.06	**0.243**
	35	**18.90**	178.57	**0.179**
	40	**16.54**	136.72	**0.137**
	45	**14.70**	108.02	**0.108**
	50	**13.23**	87.50	**0.088**
	55	**12.03**	72.31	**0.072**
	60	**11.02**	60.76	**0.061**
	65	**10.18**	51.78	**0.052**
	70	**9.45**	44.64	**0.045**
	75	**8.82**	38.89	**0.039**
	80	**8.27**	34.18	**0.034**
	85	**7.78**	30.28	**0.030**
	90	**7.35**	27.01	**0.027**
	95	**6.96**	24.24	**0.024**
	100	**6.61**	21.88	**0.022**
	105	**6.30**	19.84	**0.020**
	110	**6.01**	18.08	**0.018**
	115	**5.75**	16.54	**0.017**
	120	**5.51**	15.19	**0.015**
	125	**5.29**	14.00	**0.014**



Check: Units ok. Physics ok. Looks like Fig. 15.33

Discussion: Those core winds are not very strong compared to a tornado with a larger core pressure deficit.

A29g) (2.5 marks)

What are the Enhanced Fujita and TORRO intensity indices for a tornado of max wind speed (m/s) of: g) 80

Given: Mmax = 80 m/s

Find: EF and TORRO ratings.

Use Tables 15-3 and 15-4:

A tornado with max wind speed of 80 m/s would be rated an EF4.
A tornado with max wind speed of 80 m/s would be rated a T6.

Discussion: A tornado of EF4 and T6 can be expected to produce devastating damage. Homes could be damaged/destroyed, cars could be thrown, and wind-blown missles could pose a substantial threat.

A33g) (4 marks)

A mesocyclone at 38N is in an environment where the vertical stretching ($\Delta W/\Delta z$) is (20 m/s)/(2km). Find the rate of voticity spin-up due to stretching only, given an initial relative voriticity (/s) of: g) 0.0014.

Given:	ΔW =	20 m/s		
	Δz =	2 km	2000 m	
	ϕ =	38 deg		
	ζr =	0.0014 /s		

Find: $\Delta\zeta r/\Delta t$ (/s^2) due to stretching only.

Use stretching portion of eqn 15.51:

$$\Delta\zeta r/\Delta t = (\zeta r + fc)*(\Delta W/\Delta z)$$

where $fc = 2*\Omega*\sin\phi$ Ω = 7.29E-05 /s

fc = 8.98E-05 /s

$\Delta\zeta r/\Delta t$ = 1.49E-05 /s^2

Check: Units ok. Physics ok.

Discussion: Stretching is only part of the ingredient for tornadic rotation. Stretching results in an increase in the amount of spin in the atmosphere.

A36g) (11 marks)

Given the hodograph of winds in Fig.15.40a. Assume W=0 everywhere. Calculate helicity H based on the wind-vectors for the following pairs of heights (km): g) 0,2

Given:	W =	0	m/s		
	zf =	2	km	2000	m
	zi =	0	km	0	m

Find: H = ? m/s^2

W = 0 everywhere simplifies eqn 15.52 to 15.53:

$H = -U_{avg}*(\Delta V/\Delta z) + V_{avg}*(\Delta U/\Delta z)$

where Uavg = 0.5*(Uf + Ui) and Vavg = 0.5*(Vf + Vi)

From Fig. 15.40a:

Mi (@z=0km) =	0	m/s
Mf (@z=2km) =	10	m/s
αi (@z=0km)=	0	deg
αf (@z=2km)=	150	deg

From eqns. 1.3 and 1.4:

$U = -M*\sin(\alpha)$

$V = -M*\cos(\alpha)$

Ui =	0.00	m/s
Vi =	0.00	m/s
Uf =	-5.00	m/s
Vf =	8.66	m/s
Uavg =	-2.50	m/s
Vavg =	4.33	m/s
ΔV = Vf - Vi =	8.66	m/s
ΔU = Uf - Ui	-5.00	m/s
Δz = zf - zi =	2000	m

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H =	**-0.022 m/s^2**

Check: Units ok. Physics ok.

Discussion: Since there are no vertical winds, this value represents the streamwise-vorticity contribution to the total helicity.