ATSC 201 Fall 2024

Total marks out of 40

Chapter 15: A1f, A3f, A26f, A27f, A29f, A33f, A36f

Chapter 15

A1f)

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 troposphere. f) 175

Given:	rr=	175	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= 121450 Js-1m-2

H=	**Hrr*Δt**	**=**	**218610000**	**Jm-2**

Use eq. 15.3 ΔT/Δt = b*RR

b= 0.33 K/(mm of rain)

ΔT/Δt =	**57.75**	**K/h**

Check: Units ok. Physics ok.

Discussion: The total warming over the tropospheric depth is about 21 860 000 J/m^2 and the warming rate over the troposphere is 57.75 K/h which signifies that over half an hour the troposphere would have warmed by more than 28°C.

A3f)

Graphically estimate the terminal fall velocity of hail of diameter (cm): f) 2.1

Given:

d= 2.1 cm

Find:

wt= ? m/s

Use Fig. 15.4

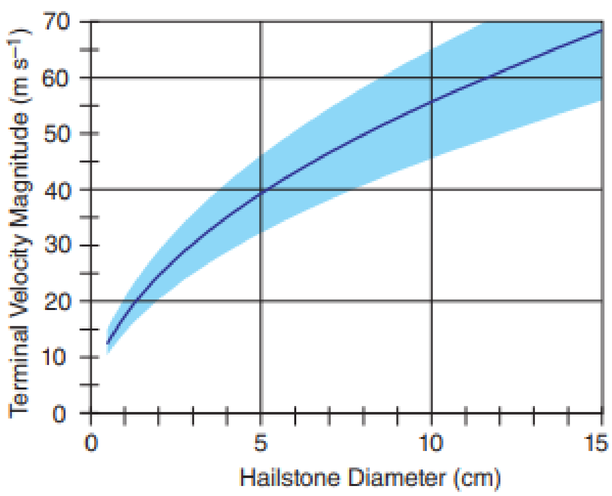


Figure 15.4
Hailstone fall-velocity magnitude relative to the air at pressure height of 50 kPa, assuming an air density of 0.69 kg m^{-3}.

wt=	25 m/s	->	accept answer between 22-28m/s

Check: **units ok**

Discussion: A hailstone with a diameter of 2.1cm is about the size of a walnut, this hailstone can reach a terminal velocity of 25m/s which is equal to 90km/h which is almost as fast as a moving car on the highway.

HW 5 Answer Key

A26f)

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: f) 70

Given:	P0=	100	kPa
	Mtanmax=	70	m/s
	rho=	1	kg/m3
Find:	ΔP = ?		kPa

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

ΔP = 4900.00 Pa

ΔP =	**4.90**	**kPa**

Check: Units ok. Physics ok.

Discussion: The pressure deficit between the ambient pressure and the tornado

core would have to be 4.9 kPa for the tangential wind to be 70 m/s, this is equivalent to the pressure difference between a low pressure core and outside of the low pressure.

A27f)

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: e) 0.6

Given:	Ro =	25	m		
	ΔP (at core) =	0.6	kPa	600	Pa

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

Inner region:

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

Outer region:

Outer Region ($R > R_o$):

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

It is evident

First, we can $\frac{M_{\tan}}{M_{\tan\max}} = \frac{R}{R_o}$ $\quad \frac{\Delta P}{\Delta P_{\max}} = \frac{1}{2}\left(\frac{R_o}{R}\right)^2$ •(15.43)

ΔP = ΔPmax = 600 Pa

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 = 24.49 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)

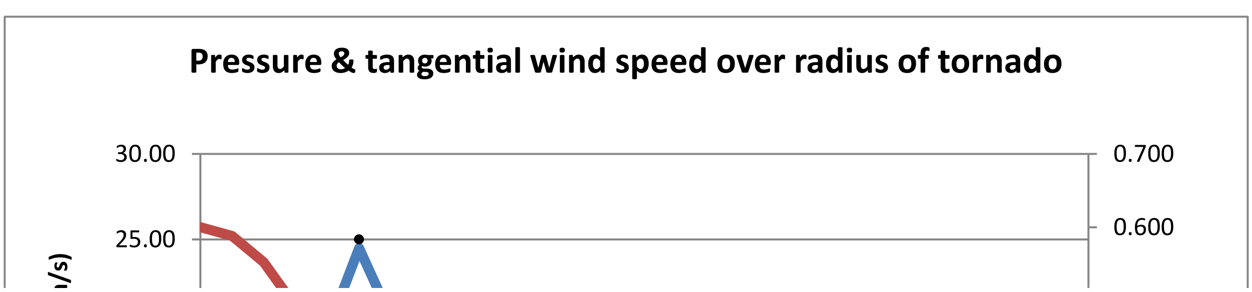
Use eqn. 15.43 for R>Ro:

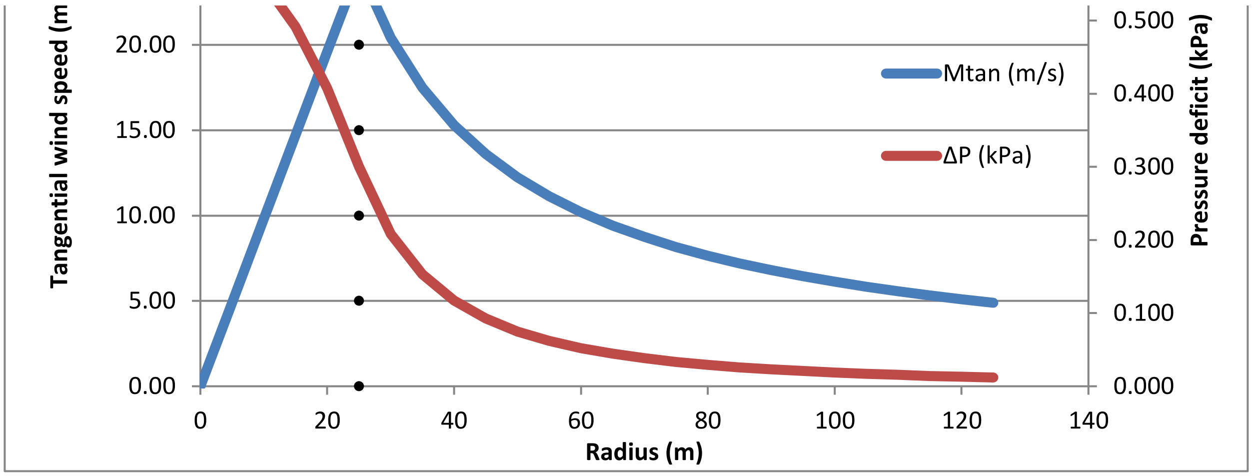
Core Region

R (m)	Mtan (m/s)	ΔP (Pa)	ΔP (kPa)	
0	**0.00**	600	**0.600**	25
5	**4.90**	588	**0.588**	25
10	**9.80**	552	**0.552**	25
15	**14.70**	492	**0.492**	25
20	**19.60**	408	**0.408**	25
25	**24.49**	300	**0.300**	25
30	**20.41**	208.33	**0.208**	

Outer Region

35	**17.50**	153.06	**0.153**
40	**15.31**	117.19	**0.117**
45	**13.61**	92.59	**0.093**
50	**12.25**	75.00	**0.075**
55	**11.13**	61.98	**0.062**
60	**10.21**	52.08	**0.052**
65	**9.42**	44.38	**0.044**
70	**8.75**	38.27	**0.038**
75	**8.16**	33.33	**0.033**
80	**7.65**	29.30	**0.029**
85	**7.20**	25.95	**0.026**
90	**6.80**	23.15	**0.023**
95	**6.45**	20.78	**0.021**
100	**6.12**	18.75	**0.019**
105	**5.83**	17.01	**0.017**
110	**5.57**	15.50	**0.015**
115	**5.32**	14.18	**0.014**
120	**5.10**	13.02	**0.013**
125	**4.90**	12.00	**0.012**





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.

A29e)

What are the Enhanced Fujita and TORRO intensity indices for a tornado of max wind speed (m/s) of: e) 70

Given: Mmax = 70 m/s

Find: EF and TORRO ratings.

Use Tables 15-3 and 15-4:

A tornado with max wind speed of 70 m/s would be rated an EF3.
A tornado with max wind speed of 70 m/s would be rated a T5.

Discussion: A tornado of EF3 and T5 can be expected to produce severe and intense damage. Roofs could be ruined, walls could collapse, windows would break, rural building can be completely destroyed and cars lifted off the ground

HW 5 Answer Key

A33f)

A mesocyclone at 38N is in an environment where the vertical stretching (ΔW/Δz) is (20 m/s)/(2km). Find the rate of voticity spin-up due to stretching only, given an initial relative voriticity (/s) of: f) 0.0012.

Given:	ΔW =	20	m/s		
	Δz =	2	km	2000	m
	ϕ =	38	deg		
	ζr =	0.0012	/s		

Find: Δζr/Δt (/s^2) due to stretching only.

Use stretching portion of eqn 15.51:

Δζr/Δt = (ζr + fc)*(ΔW/Δz)

where fc = 2*Ω*sinϕ   Ω = 7.29E-05 /s

fc = 8.98E-05 /s

Δζr/Δt = 1.29E-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.

A36f)

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): e) 5,6

Given:	W =	0	m/s		
	zf =	6	km	6000	m
	zi =	5	km	5000	m

Find: H = ? m/s^2

W = 0 everywhere simplifies eqn 15.52 to 15.53:

H = -Uavg*(ΔV/Δz) + Vavg*(ΔU/Δz)

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

From Fig. 15.40a:

Mi (@z=5km) =	20	m/s
Mf (@z=6km) =	30	m/s
αi (@z=5km)=	220	deg
αf (@z=6km)=	240	deg

From eqns. 1.3 and 1.4:

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

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

Ui =	12.86	m/s
Vi =	15.32	m/s
Uf =	25.98	m/s
Vf =	15.00	m/s
Uavg =	19.42	m/s
Vavg =	15.16	m/s
ΔV = Vf - Vi =	-0.32	m/s
ΔU = Uf - Ui =	13.13	m/s
Δz = zf - zi =	1000	m

H = 0.205212086 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.