HW 6 Answer Key

ATSC 201 Fall 2024
Chapter 3: A10e, A14e, A15, A20e, A27e, E1
Total mark out of 28

Chapter 3

A10f)
(3.5 marks)

Given air with temperature and altitude as listed below, use formulas (not thermo diagrams) to calculate the potential temperature. Show all steps in your calculations. f) z(m) = 6000, T(degC) =-50

Given:	z =	6000	m
	T =	-50	deg C

Find:	θ(z)	?	deg C

Use eqn 3.11:

$$\theta(z) = T(z) + \Gamma_d \cdot z \qquad (3.11)$$

Use eqn. 3.8:

$$\Gamma_d = 9.8 \text{ K km}^{-1} = 9.8 \text{ °C km}^{-1}$$

Convert z(m) into z(km):

z =	6	km

θ(z) =	**8.80**	**deg C**
	281.95	**K**

Check: Units ok. Physics ok.

Discussion: This is the temperature that a parcel at height of 6km would have if it were brought down to z=0 dry adiabatically. Potential temperature is constant through dry adiabatic processes.

$$\theta_v = \theta \cdot [1 + (a \cdot r)] \qquad (3.13)$$

A14f)
(3 marks)

Instead of equations, use the Fig 3.4 to find the actual air temperature (degC) given: f) P(kPa) = 50, θ(degC) = 10.

Given:	P =	50	kPa

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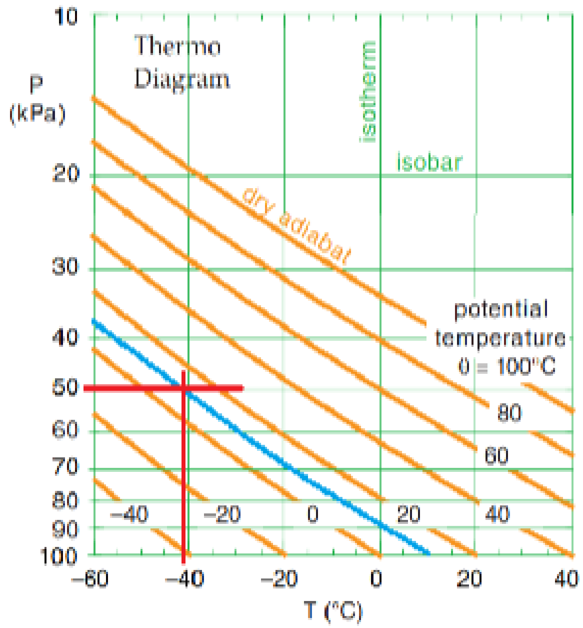
θ = 10 degC

Find: T = ? deg C

Using thermo diagram:



T = -40 degC

Check: Units ok.

Discussion: Thermo diagrams are easy to use as seen in this question to convert between potential temperature and air temperature

A15)
(7.5 marks)

Use a spreadsheet to calculate and plot a thermo diagram similar to Fig. 3.4 but with isotherm grid lines every 10degC, and dry adiabats for every 10degC from -50degC to 80degC.

Use eqn. 3.10:

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\Re_d / C_p} \quad \bullet(3.10)$$

Rd/cp = 0.28571

Each T(degC) column is a dry adiabat

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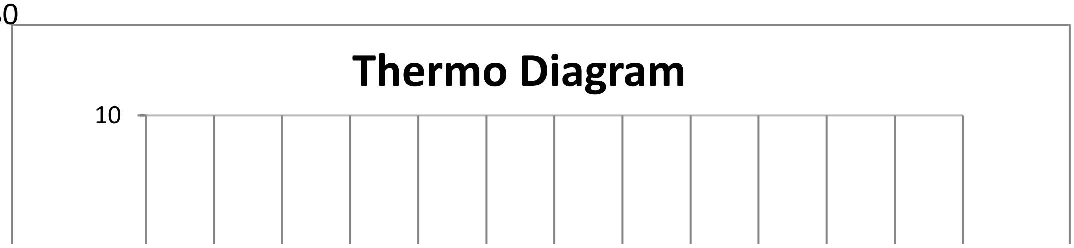
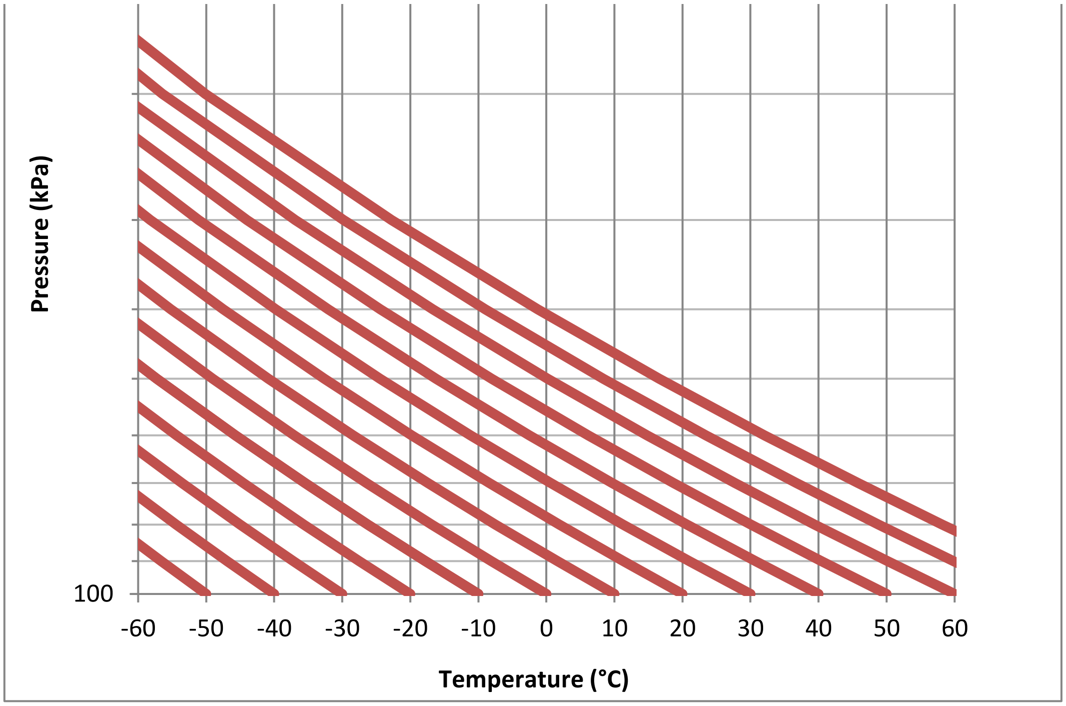
P (kPa)	T (degC)	T (degC)	T (degC)	T (degC)	T (degC)	T (degC)
10	-157.49657	-152.31705	-147.13752	-141.958	-136.77847	-131.59895
20	-132.20017	-125.88627	-119.57238	-113.25848	-106.94459	-100.6307
30	-114.9068	-107.81742	-100.72804	-93.638662	-86.549281	-79.4599
40	-101.36359	-93.66689	-85.97019	-78.27349	-70.57679	-62.880089
50	-90.064672	-81.861294	-73.657916	-65.454538	-57.25116	-49.047782
60	-80.282809	-71.640783	-62.998756	-54.35673	-45.714703	-37.072676
70	-71.605399	-62.574251	-53.543103	-44.511955	-35.480807	-26.449659
80	-63.773494	-54.391139	-45.008785	-35.62643	-26.244076	-16.861721
90	-56.612838	-46.909378	-37.205918	-27.502458	-17.798998	-8.0955374
100	-50	-40	-30	-20	-10	0.0000001

T (degC)	T (degC)	T (degC)	T (degC)	T (degC)	T (degC)	T (degC)
-126.41942	-121.23989	-116.06037	-110.88084	-105.70132	-100.52179	-95.342265
-94.316802	-88.002909	-81.689015	-75.375121	-69.061227	-62.747333	-56.433439
-72.370519	-65.281138	-58.191757	-51.102376	-44.012995	-36.923614	-29.834234
-55.183389	-47.486689	-39.789989	-32.093289	-24.396589	-16.699889	-9.0031894
-40.844405	-32.641027	-24.437649	-16.234271	-8.0308929	0.17248504	8.37586297
-28.43065	-19.788624	-11.146597	-2.5045705	6.13745598	14.7794825	23.421509
-17.418511	-8.3873626	0.64378539	9.67493343	18.7060815	27.7372295	36.7683775
-7.4793664	1.90298812	11.2853427	20.6676972	30.0500518	39.4324063	48.8147608
1.6079227	11.3113829	21.014843	30.7183032	40.4217634	50.1252235	59.8286837
10	20	30	40	50	60	70

T (degC)
-90.16274
-50.119545
-22.744853
-1.3064893
16.5792409
32.0635355
45.7995256
58.1971154
69.5321439
80





Check: Units ok. Physics ok.

Discussion:

A thermo diagram is useful in many ways, including determining quickly the stability of different layers in the atmosphere, based on temperature soundings, to predict whether clouds and thunderstorms will form.

A20f)
(3 marks)

Find the effective surface turbulent heat flux (°C*m/s) over a forest for wind speed of 10 m/s, air tempertaure of 20 °C, and surface temperature (°C) of: f) 26.

Given:	Ta =	20	°C
	Ts =	26	°C
	M =	10	m/s

Find: FH = ? °C*m/s

Use eqn. 3.35:

FH = CH*M*(Ts-Ta)

where CH = 2.00E-02 for forests

FH =	1.20 °C*m/s

Check: Units ok. Physics ok.

Discussion: For every degree Celsius difference between the surface temperature and the air temperature, the effective surface turbulent heat flux increases by 0.2 degC*m/s for a given wind speed of 10m/s. The stronger the winds are, the greater the increase in the effective surface turbulent heat flux.

A27f)
(4 marks)

Given a pre-storm environment where the temperature varies linearly from 25°C at the Earth's surface to -60°C at 11km (tropopause). What is the value of the vertical gradient of turbulent flux (K/s) for an altitude (km) of: f) 2.5km

Given:	zT =	11 km		
	z =	2.5 km		
	Γsa =	6.5 K/km		
	Δt =	1 hr		3600 s

Find: ΔFz/Δz = ? K/s

First find initial lapse rate using eqn. 3.6:

$$\Gamma = -\frac{T_2 - T_1}{z_2 - z_1} = -\frac{\Delta T}{\Delta z} \qquad (3.6)$$

where T2 =	-60 degC	213.15 K
T1 =	25 degC	298.15 K

z2 = zT =	11 km
z1 =	0 km

Γps = 7.72727273 degC/km = K/km

Now use eqn. 3.43:

$$\frac{\Delta F_{z\ turb}}{\Delta z} \approx \frac{z_T}{\Delta t} \cdot \left[\Gamma_{ps} - \Gamma_{sa}\right] \cdot \left(\frac{1}{2} - \frac{z}{z_T}\right) \qquad (3.43)$$

ΔF/Δz =	0.00102 K/s

Check: Units ok. Physics ok.

Discussion: The vertical turbulent flux gradient mixes the pre-storm air until the temperature profile returns to that of the standard atmosphere

E1)
(7 marks)

Assume that 1kg of liquid water initially at 15°C is in an insulated container. Then you add 1kg of ice into the container. The ice melts and the liquid water becomes colder. Eventually a final equilibrium is reached. Describe what you end up with at this final equilibrium?

Given:	Ti =	15	°C		
	m_water =	1	kg		
	m_ice =	1	kg		
	Lf =	334	kJ/kg	3.34E+05	J/kg
	C_liquid =	4.218	kJ/(kg*degC)	4218	J/(kg*degC)

Assume ice has an initial temperature of 0°C

An insulated container is an isolated system. This means that the water and ice only give/take energy from each other, not their surroundings. So equilibrum is reached when the water reaches a temperature of 0°C and the ice stops melting, OR, when all ice has melted and the water is still above 0°C.

Find energy required to melt all of the ice:

$\Delta qe = \Delta m\_ice * Lf$

$\Delta qe =$ 334000 J

Use eqn. 3.4b to find how much energy released when water cools to 0°C. This is how much energy we have available to melt the ice.

$\Delta Qh = m\_water * C\_liquid * \Delta T$

where $\Delta T =$ -15 °C

$\Delta Qh =$ -63270 J

The water will cool to 0°C and release 63270 J of energy (sensible heat). This energy is transferred to the ice, but it is not enough energy to melt ALL the ice (which would take 334000 J). But SOME of the ice will melt.

Now find Δm_ice (how much of the ice will melt) given $\Delta qe = 63270$ J

$\Delta m\_ice = \Delta qe/Lf$ (just equation 3.1 but rearranged)

$\Delta m\_ice = -0.189$ kg

which means 0.189kg of ice has melted before the water and ice are in an equilibrium state at 0°C.

Finally find how much ice is left as solid:

$\Delta m\_ice\_unmelted = m\_ice\_initial - m\_ice\_melted$

$= 1\text{kg} - 0.189\text{kg}$

$= 0.811$ kg

And how much water we have at the end:

M_water = 1 kg + 0.189 kg = 1.189 kg

final state:

T = 0°C for the water and ice.
m_ice = 0.811kg of ice is still in the water.
M_water = 1.189 kg of water is in the container.

Check: Units ok. Physics ok.

Discussion: In a non-insulated container, the ice would fully melt and equilibrium would not be reached until the water is the same temperature as the surrounding air.