EAS270, "The Atmosphere" Mid-term Exam 28 Oct. 2009

Professor: J.D. Wilson Time available: 45 mins Value: 20%

Instructions: For all 30 multi-choice questions, choose what you consider to be the best (or most logical) option. Use a pencil to mark that choice on the answer form. ***Equations and data given at back***. ***You may keep this exam***

Note added after exam: in addition to understanding why the indicated answers are correct, it is equally useful to clarify for yourself why the other options would have been incorrect.

1. If a sample of air has vapour pressure $e = 14$ hPa then the dewpoint temperature of that sample T_d is closest to ____ °C

   (a) 0
   (b) 12 ✓✓ [use Table]
   (c) 14
   (d) 18
   (e) 20

2. If a sample of air has relative humidity $RH = 50\%$ and its temperature is $T_d = 19$°C then its vapour pressure e is closest to ____ hPa

   (a) 3
   (b) 5
   (c) 7
   (d) 9
   (e) 11 ✓✓ [$e_s(19) = 22\,\text{hPa};\ e = 22 \times 50/100 = 11\,\text{hPa}$]

3. The possibility to have formation of haze at relative humidities less than 100% owes to the presence in the air of ____

   (a) condensation nuclei ✓✓ [p148, p164]
   (b) ice nuclei
   (c) supersaturation
   (d) supercooled cloud droplets
   (e) silver iodide

4. On Mars the gravitational acceleration $g = 3.7\,\text{m}\,\text{s}^{-2}$, and the Martian atmosphere of carbon dioxide has specific heat capacity $c_p = 736$ [$\text{J}\,\text{kg}^{-1}\,\text{K}^{-1}$]. Thus on Mars a parcel lifted dry adiabatically through a distance of 100 m would ____

   (a) warm by about 5 K
   (b) cool by about 5 K
   (c) warm by about 0.5 K
   (d) cool by about 0.5 K ✓✓ [substitute into given eqn for lapse rate]
   (e) cool by about 0.05 K

5. In adiabatic ascent of an unsaturated parcel, which water vapour variable remains unchanged?

   (a) Relative humidity RH
   (b) Absolute humidity ρ_v
   (c) Specific humidity q ✓✓ [p138]
   (d) Vapour pressure e
   (e) Dewpoint temperature T_d

6. "Absolute instability" of the atmosphere commonly occurs ____

   (a) in the lower stratosphere
   (b) in the upper troposphere
   (c) at night
   (d) in a shallow ground-based layer during daytime heating ($Q_H > 0$) ✓✓ [p176; slide #6, lecture 16]
   (e) during the formation of a radiation fog

7. Collision efficiency for cloud droplets of radius r, R ____

   (a) is near unity for $r \ll R$
   (b) is near unity for $r \gg R$
   (c) is near unity for $r \approx R$
   (d) is a maximum in warm clouds
   (e) is much smaller than unity if $r \ll R$ or if $r \gg R$ ✓✓ [p205]

8. The radius of a typical cloud droplet is of order ____

   (a) 0.1 μm
   (b) 10 μm ✓✓ [Fig. 7-3]
   (c) 1000 μm
   (d) 10 mm
   (e) 10 cm

9. Small spherical particles of radius r fall relative to still air with a terminal velocity V_t that varies in proportion to ____

   (a) $1/r$ (i.e. terminal velocity is halved if radius is doubled)
   (b) $1/\sqrt{r}$
   (c) $\sqrt{r}$ ✓✓ [p203]
   (d) r
   (e) r^2

10. The Bergeron process for migration of water from supercooled droplets to ice crystals depends on the difference in ____ between surfaces of ice and water

   (a) equilibrium vapor pressure ✓✓ [p206]
   (b) temperature
   (c) density
   (d) terminal velocity
   (e) vertical velocity

11. Specific humidity is the ratio $q = m_v/m$ of the mass of water vapour in a given volume to the total mass $m = m_v + m_d$. If an unsaturated parcel is lifted ____

   (a) q decreases at the Saturated Adiabatic Lapse Rate (SALR)
   (b) q decreases at the Dry Adiabatic Lapse Rate (DALR)
   (c) q decreases at the Environmental Lapse Rate (ELR)
   (d) q increases
   (e) q remains unchanged ✓✓ [p138]

12. A parcel of dry air ascending 100m adiabatically in earth's atmosphere cools by ____ degrees Celcius. However due to ____ , the cooling experienced by a saturated parcel covering the same path is ____ than this amount.

   (a) ten; entrainment of colder environmental air; more
   (b) ten; entrainment of warmer environmental air; less
   (c) ten; release of latent heat of condensation; less
   (d) one; release of latent heat of condensation; more
   (e) one; release of latent heat of condensation; less ✓✓ [p155]

13. The collection of supercooled cloud droplets by a falling ice crystal is a process called ____

   (a) the solute effect
   (b) the curvature effect
   (c) riming ✓✓ [p207]
   (d) aggregation
   (e) graupellation

14. When a warm, almost saturated wind blows over a frozen lake, the result may be ____

   (a) lake-effect snowfall
   (b) advection fog ✓✓ [p160]
   (c) formation of convective cloud over the lake
   (d) freezing rain
   (e) radiation fog

15. Which association is false?

    (a) Cirrus - wispy
    (b) Cumulus - heapy
    (c) Stratus - layered
    (d) Nimbus - producing rain, hail or snow
    (e) Orographic - produced by dry, cool airflow over very warm ocean ✓✓ [p170]

16. If the sky is overcast yet the sun casts shadows and is surrounded by a halo, the cloud type is ____

    (a) Cirrostratus ✓✓ [p186]
    (b) Sratocumulus
    (c) Stratus
    (d) Nimbostratus
    (e) Altostratus

17. Suppose in a certain layer of the atmosphere the environmental lapse rate ELR = $+0.05°\mathrm{C\,m^{-1}}$, ie. for every 1 m increase in altitude, the temperature increases by 0.05°C. This layer is ____

    (a) unconditionally stable ✓✓ [p178; it was noted in the exam that "unconditionally" and "absolutely" have the same meaning]
    (b) unconditionally unstable
    (c) conditionally unstable
    (d) conditionally stable
    (e) neutral with respect to dry adiabatic motion

18. The idealized three-cell model of the general circulation predicts low-level easterlies at low latitude ('trade winds') and at high latitude ('polar easterlies'). In reality easterly trade winds are ____ and the polar easterlies are ____

    (a) a persistent weather feature; a persistent weather feature
    (b) a persistent weather feature; visible only as a climatological feature ✓✓ [p231]
    (c) visible only as a climatological feature; a persistent weather feature
    (d) westerlies; easterlies
    (e) easterlies; westerlies

19. The 3-cell model for the General Circulation suggests that at latitude 30 degrees one will find ____ surface pressure while at latitude 60 degrees one will find ____ surface pressure.

    (a) Low; low
    (b) High; high
    (c) High; low ✓✓ [Fig. 8-3]
    (d) Low; high
    (e) Negative; positive

20. Regarding semipermanent pressure systems of the general circulation, that which is most significant for winter weather in western Canada is the ____

    (a) Siberian High
    (b) Aleutian Low ✓✓ [p234; slide #8, lec19]
    (c) Icelandic Low
    (d) Hawaiian High
    (e) Tibetan Low

21. Strong deviations of temperature away from the climatological norm are likely to occur during a sustained period of ____ flow associated with a ____ long wave (Rossby wave) pattern

    (a) zonal; large amplitude
    (b) zonal; gently meandering
    (c) meridional; large amplitude ✓✓ [p239]
    (d) meridional; gently meandering
    (e) westerly; gently meandering

22. An afternoon sea-breeze is most likely to occur ____

    (a) after a sunny, calm morning ✓✓ [maximizing the differential heating rate]
    (b) after a cloudy, windy morning
    (c) after a cloudy, calm morning
    (d) after a rainy, calm morning
    (e) in conjunction with a cyclonic storm

23. The Walker circulation is a feature of the observed General Circulation (GC) in the equatorial Pacific that ____

    (a) redistributes energy and water vapour across longitude lines ✓✓ [Fig. 8-29]
    (b) redistributes energy and water vapour across latitude lines
    (c) is one of the three "cells" of the 3-cell GC Model
    (d) occurs within the polar cell of the 3-cell GC Model
    (e) is unrelated to the El-Nino phenomenon

24. A deep layer of fog is more likely to form on a night with a very gentle wind, than during a night which is completely calm, because ____

    (a) rate of longwave radiant emission from ground is increased by wind
    (b) eddies carry heat down to the cooling surface from a deeper layer ✓✓ [p159]
    (c) a light wind increases the rate of cooling of the ground
    (d) the ELR equals the DALR
    (e) the light breeze prevents gravitational settling of condensation nuclei

For the remaining questions, please refer to the attached charts.

25. Heavy short-dashed lines on the skew T-log p diagram (Figure 1) identify several families of reference curves. The family of dry adiabats is represented by line ____
    (a) A
    (b) B ✓✓ [slide #11 lec13]
    (c) C
    (d) D
    (e) E

26. Layer L1 should be classified as ____
    (a) absolutely unstable
    (b) absolutely stable
    (c) conditionally unstable
    (d) conditionally stable
    (e) neutral with respect to dry adiabatic motion ✓✓ [slide #20, lec14]

27. The ground-based layer below layer L1 is ____
    (a) absolutely unstable ✓✓
    (b) absolutely stable
    (c) conditionally unstable
    (d) conditionally stable
    (e) neutral with respect to dry adiabatic motion

28. Comparing Figures (2,3) the change in 1000-500 hPa thickness at Edmonton was about ____
    (a) 35 m
    (b) 62 m
    (c) 35 dam ✓✓ [thickness changes from about 549 dam to about 514 dam]
    (d) 62 dam
    (e) 350 dam

29. Corresponding to the above thickness change of n dam, the mean temperature of the 1000-500 hPa layer over Edmonton had ____ during the interval by ____ degrees Kelvin
    (a) warmed; $2n$
    (b) cooled; $2n$
    (c) warmed; $n/2$
    (d) cooled; $n/2$ ✓✓ [slide #2 lec15]

30. Figure (4) gives the Edmonton sounding data up to 700 hPa for two times. The change in thickness of the 925-850 hPa layer during the interval was a/an ____ of about ____ [m]

  (a) decrease; 40 ✓✓ [slide #10 lec15. At the earlier time: 1488-792=696 m; at later time 1416=7-761=656 m. Thus a decrease of 40 m]
  (b) decrease; 700
  (c) increase; 40
  (d) increase; 700

Equations and Data

- $Q^* = Q_H + Q_E + Q_G$

  Surface energy balance on a reference plane at the base of the atmosphere, all fluxes in [W m^{-2}]. Q^* the net radiation, positive if directed towards the surface; Q_H, Q_E the sensible and the latent heat fluxes, positive if directed from the surface towards the atmosphere; Q_G the 'soil' heat flux, positive if directed from the surface into ground/lake/ocean.

- $\frac{\Delta T}{\Delta z} = -\frac{g}{c_p}$

  The dry adiabatic lapse rate, where g is the gravitational acceleration and c_p [J kg^{-1} K^{-1}] is the specific heat at constant pressure.

- e, ρ_v, $q = m_v/(m_v + m_d) = \rho_v/\rho$, T_d, RH$= 100\, e/e_s(T)$

  Humidity variables: e [Pa] the vapour pressure; ρ_v [kg m^{-3}] the absolute humidity vapour density); q the specific humidity (where m_v, m_d are respectively the mass of vapour and of "dry air" in a sample); T_d the dewpoint temperature; and RH the relative humidity (where $e_s(T)$ is the equilibrium vapour pressure corresponding to temperature T of the sample)

Table 1: Equilibrium vapour pressure $e_s(T)$ [hPa] versus temperature T [°C]. Figure cited applies to equilibrium over a plane surface of water where $T \geq 0$°C, or of ice where $T < 0$°C.

T	$e_s(T)$	T	$e_s(T)$	T	$e_s(T)$	T	$e_s(T)$	T	$e_s(T)$	T	$e_s(T)$	T	$e_s(T)$
-5	4.02	0	6.11	5	8.72	10	12.27	15	17.04	20	23.37	25	31.67
-4	4.37	1	6.57	6	9.35	11	13.12	16	18.17	21	24.86	26	33.61
-3	4.76	2	7.05	7	10.01	12	14.02	17	19.37	22	26.43	27	35.65
-2	5.17	3	7.58	8	10.72	13	14.97	18	20.63	23	28.09	28	37.80
-1	5.62	4	8.13	9	11.47	14	15.98	19	21.96	24	29.83	29	40.06

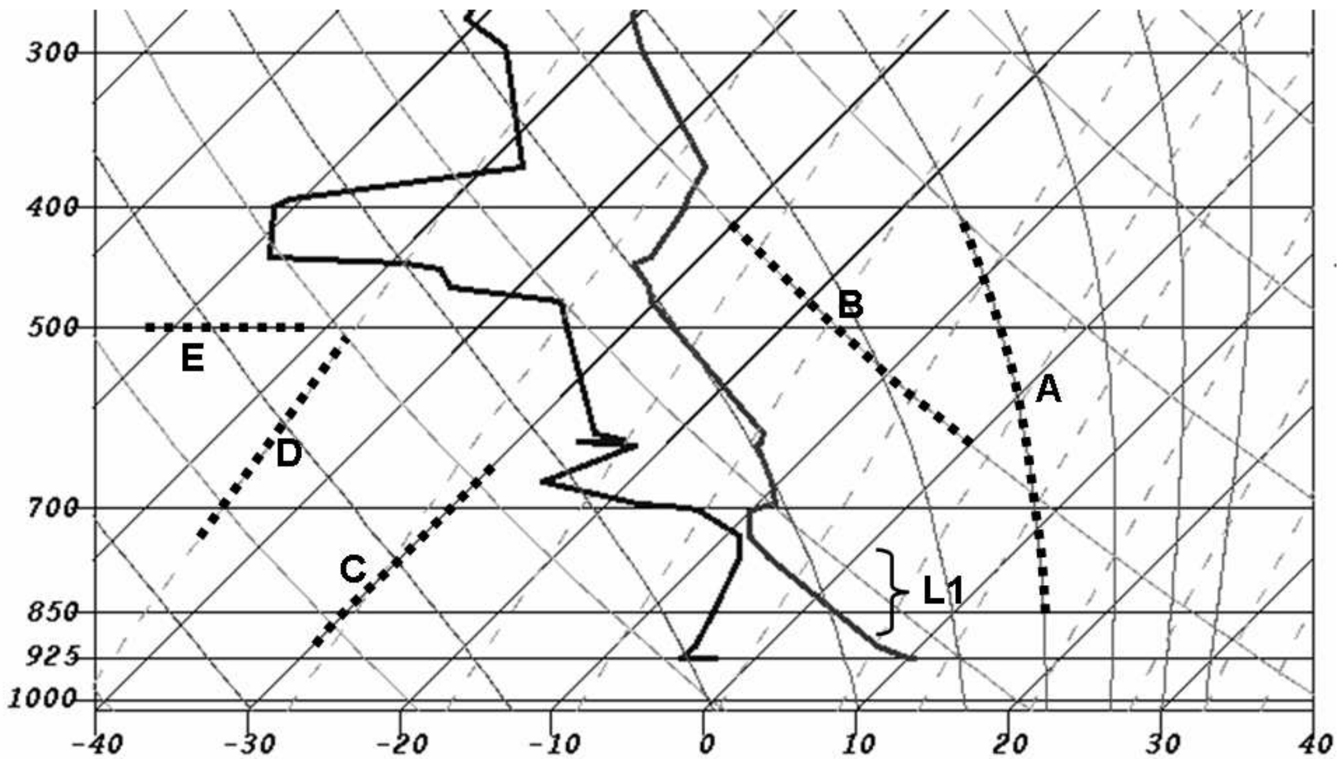

Figure 1: Thermodynamic chart for Edmonton, 00Z 1 Oct. 2009.

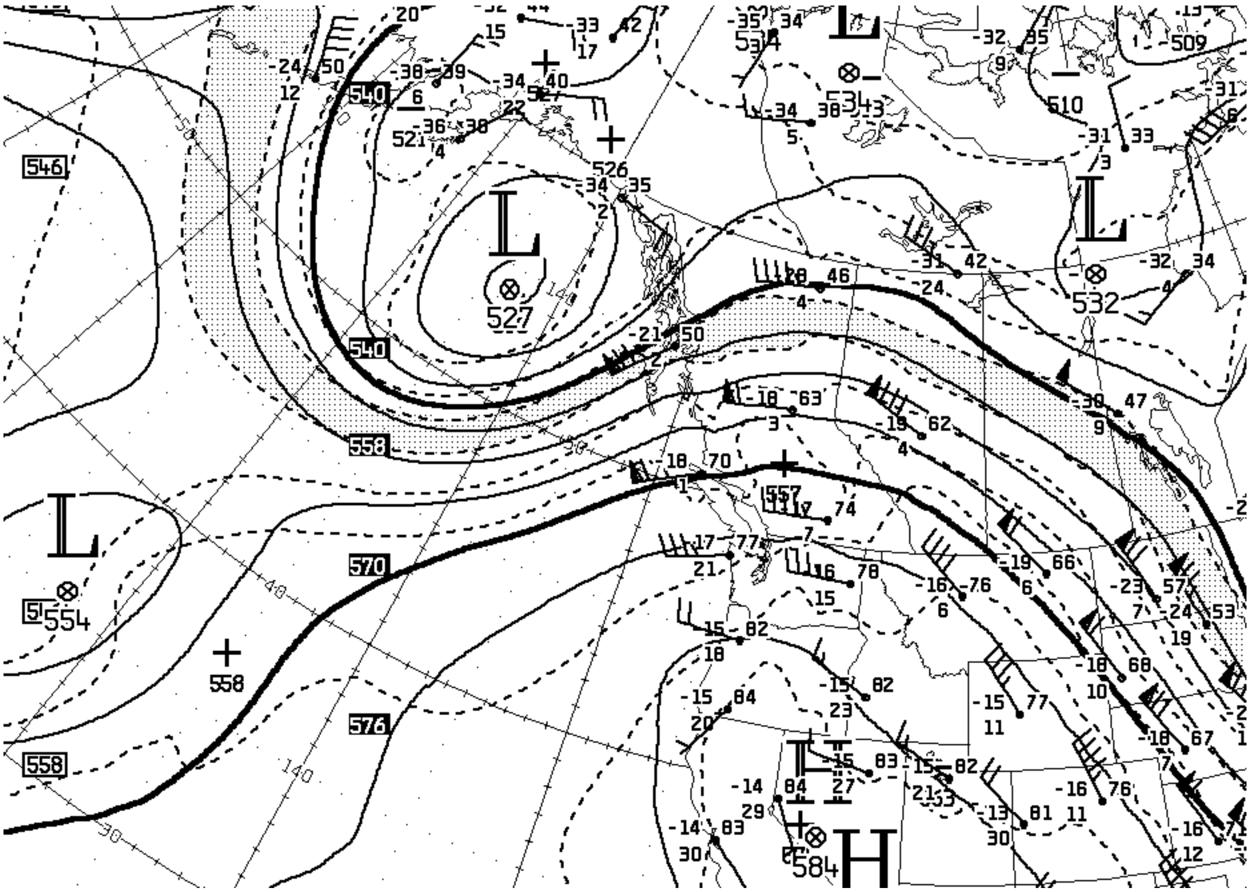

Figure 2: CMC 500 hPa analysis for 00Z 21 April 2009. Boxes with white text on a black background label height contours, boxes with black text on a white background label thickness contours.

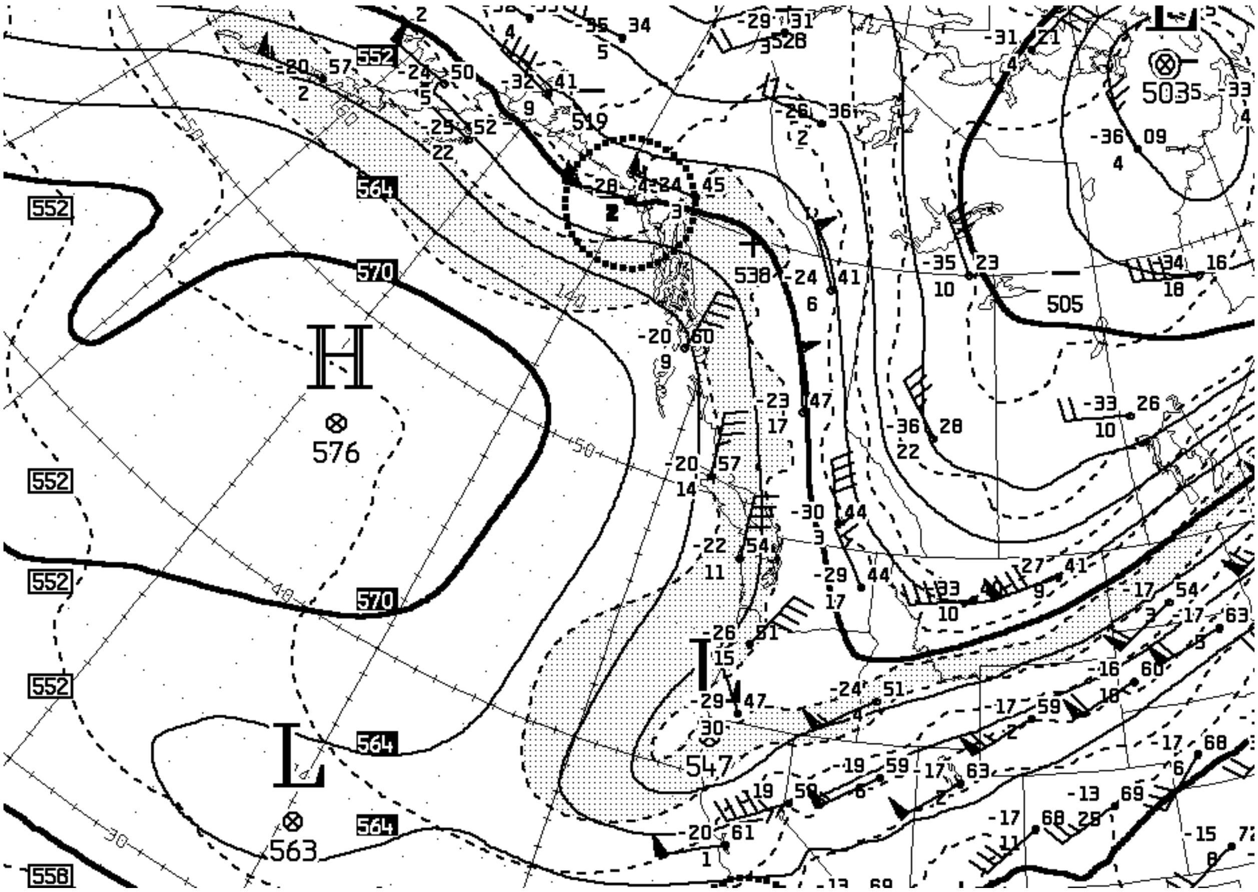

Figure 3: CMC 500 hPa analysis for 12Z 24 April 2009. Boxes with white text on a black background label height contours, boxes with black text on a white background label thickness contours.

00Z, 21 April 2009

PRES hPa	HGHT m	TEMP C
1000.0	134	
928.0	766	12.2
926.0	783	11.4
925.0	792	11.2
911.4	914	10.1
878.2	1219	7.4
850.0	1488	5.0
846.2	1524	4.6
836.0	1623	3.6
815.1	1829	2.6
807.0	1910	2.2
784.9	2134	1.9
781.0	2174	1.8
755.6	2438	-0.3
727.2	2743	-2.7
700.0	3047	-5.1

12Z, 24 April 2009

PRES hPa	HGHT m	TEMP C
1000.0	142	
925.0	761	
924.0	766	-6.7
919.0	809	-6.9
906.7	914	-7.4
887.0	1086	-8.3
872.0	1219	-9.4
850.0	1417	-11.1
838.1	1524	-11.9
805.3	1829	-14.3
792.0	1956	-15.3
773.5	2134	-16.7
755.0	2316	-18.1
742.6	2438	-19.1
712.7	2743	-21.7
708.0	2792	-22.1
700.0	2876	-22.5

Figure 4: Edmonton soundings.