Professor: J.D. Wilson <u>Time available</u>: 120 mins <u>Value</u>: 42%

Instructions: For all 70 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 (you may keep this exam). *See back page for equations and data you may need*.

- 1. Approximately what percentage of atmospheric mass lies below the 10 mb level?
 - (a) 10%
 - (b) 90%
 - (c) 1%
 - (d) 99% ✓
 - (e) 66%

2. The two most abundant permanent gases in today's atmosphere are _____

- (a) $N_2, O_2 \checkmark$
- (b) N_2, CO_2
- (c) O_2, CO_2
- (d) H_2O, N_2
- (e) Ar, CO_2
- 3. The rate of change of pressure with height $(\Delta p/\Delta z)$ on the 850 mb surface is _____ the temperature T_{850} at that level.
 - (a) Proportional to
 - (b) Inversely proportional to \checkmark
 - (c) Independent of
 - (d) Proportional to the square of
 - (e) Unrelated to
- 4. To assess the stability of an atmospheric layer, we compare the _____ against theoretical benchmark(s) _____
 - (a) ELR; DALR
 - (b) DALR; SALR
 - (c) ELR; DALR, SALR \checkmark
 - (d) DALR; ELR, SALR
 - (e) SALR; ELR, DALR

- 5. When averaged over a large area (eg. over all of Saskatchewan) at a specific time, the vertical velocity above the friction layer is usually _____
 - (a) non-zero, but much smaller than the horizontal velocity \checkmark
 - (b) much larger than the horizontal velocity
 - (c) zero
 - (d) large and negative
 - (e) large and positive
- 6. Ozone is present in the stratosphere at a concentration of approximately _____
 - (a) 370 ppm
 - (b) 20 %
 - (c) 10 ppm ✓
 - (d) 1 kg m^{-3}
 - (e) 10 kg m^{-3}

7. In atmospheric science the "solar constant" refers to _____

- (a) the inclination (23.5 degrees) of earth's spin axis relative to the plane of its orbit
- (b) the radius (about 150 million km) of earth's orbit about the sun
- (c) the strength of the solar wind
- (d) the incident terrestrial radiant energy flux density (1370 ${\rm W~m^{-2}})$ above the atmosphere
- (e) the incident solar radiant energy flux density (1370 W m⁻²) above the atmosphere \checkmark
- 8. Suppose the incoming solar radiation flux on a fresh snowpack is $K \downarrow = 100 \text{ W m}^{-2}$. If the albedo of the snowpack is 80%, then the reflected solar radiation flux $K \uparrow$ is _____
 - (a) 80 W m⁻² \checkmark
 - (b) 20 W m^{-2}
 - (c) 180 W m^{-2}
 - (d) 120 W m^{-2}
 - (e) None of the above
- 9. Earth's axis of rotation (spin) is inclined by _____ degrees away from the perpendicular to the plane defined by its orbit around the sun. The "solstices" are the times of the year when there is _____ difference between day-length and night-length.
 - (a) 45; maximum
 - (b) 23.5; zero
 - (c) 90; zero

- (d) 23.5; minimum
- (e) 23.5; maximum \checkmark
- 10. When we say the atmosphere is in a state of "hydrostatic equilibrium (or balance)" we refer to the near equality of the _____ and _____ forces.
 - (a) gravity; Coriolis
 - (b) Coriolis; horizontal pressure-gradient
 - (c) gravity; horizontal pressure-gradient
 - (d) gravity; vertical pressure-gradient \checkmark
 - (e) horizontal pressure-gradient; vertical pressure-gradient
- 11. In the atmospheric boundary layer, friction retards the wind. The mechanism of this friction is _____
 - (a) gravity
 - (b) the pressure gradient
 - (c) the Coriolis force
 - (d) turbulent convective transport of momentum between adjacent air layers \checkmark
 - (e) inter-molecular attractive force ("viscosity")
- 12. Due to the absence of topographic barriers, the climatological winds at middle latitudes of the southern hemisphere are _____
 - (a) Meridional
 - (b) Zonal westerlies \checkmark
 - (c) Northerlies
 - (d) Easterlies
 - (e) Southerlies
- 13. A parcel of air is resting at an elevation where its density $\rho \approx 1 \text{ kg m}^{-3}$. Assume the parcel now moves and its pressure is increased adiabatically by 100 Pa: in consequence the parcel's _____
 - (a) temperature increases by about 0.1 C \checkmark
 - (b) temperature decreases by about 0.1 C
 - (c) temperature increases by about 1 C
 - (d) temperature decreases by about 1 C
 - (e) relative humidity is constant

- 14. When sprinkling a valuable fruit as a means of avoiding frost damage, it is important that the water arrive on the surface of the fruit in the _____ state. This is so that _____ will be delivered to the surface of the fruit, and ensures that the surface ice/water film has a temperature of about _____
 - (a) frozen; specific heat; 1 C
 - (b) frozen; sensible heat; 0 C
 - (c) frozen; latent heat; 1 C
 - (d) liquid; specific heat; 0 C
 - (e) liquid; latent heat; 0 C \checkmark
- 15. If the wind is blowing with speed U perpendicular to surface isotherms then "temperature advection" is occurring. If the isotherm spacing implies an alongwind temperature gradient of strength ΔT [C] per each increment Δx [m] of alongwind distance, then the rate of temperature advection is _____
 - (a) $\frac{\Delta T}{\Delta x}$
 - (b) $U \frac{\Delta T}{\Delta x} \checkmark$
 - (c) $U \Delta T$
 - (d) $U/\Delta x$
 - (e) $U/\Delta T$

16. A halo around the sun or moon is associated with _____ clouds

- (a) nimbostratus
- (b) stratocumulus
- (c) altocumulus
- (d) cirrostratus \checkmark
- (e) altostratus

17. The designation "scattered clouds" means

- (a) no clouds are visible at any level
- (b) clouds cover up to one tenth of the sky
- (c) clouds cover up to two tenths of the sky
- (d) clouds cover between one tenth and one half of the sky \checkmark
- (e) no low or middle clouds, but up to one tenth of the sky covered by high cloud
- 18. The central pressure P_c at the axis of a tornado is much lower than the ambient pressure P_o . The equation $P_o P_c = \rho V^2$ relates the tangential windspeed V to the pressure deficit in the tornado, and derives from equating _____
 - (a) pressure-gradient and Coriolis forces

- (b) pressure-gradient force and centripetal acceleration \checkmark
- (c) Coriolis force and centripetal acceleration
- (d) gravitational force and centripetal acceleration
- (e) none of the above
- 19. Imagine a closed container containing only water and water vapor. This system is isothermal (its temperature T is uniform in space and constant in time) and has been allowed to reach equilibrium. The rate of evaporation of liquid water _____ the rate of condensation of gaseous water. The water vapor pressure (e) _____ and the Relative Humidity (RH) if the temperature of the container is increased.
 - (a) exceeds; increases; increases
 - (b) exceeds; increases; is steady at 100%
 - (c) balances; increases; is steady at 100% \checkmark
 - (d) equals; decreases; decreases
 - (e) is less than; is unchanged; is unchanged
- 20. When a cloud droplet or a rain drop of mass m is falling at its terminal velocity, the net force on the particle is _____
 - (a) directed towards ground
 - (b) directed horizontally
 - (c) zero \checkmark
 - (d) m g (where g is gravitational acceleration)
 - (e) $\frac{1}{2} m g$
- 21. The water constituting a rain drop is held together, ie. remains stable in the form of an intact volume, due to the action of _____
 - (a) viscosity
 - (b) gravity
 - (c) entrainment
 - (d) wind drag
 - (e) surface tension \checkmark
- 22. The summertime counterpart of the wintertime Siberian High, ie. the feature dominating summer weather in Asia, is the _____
 - (a) Tibetan Low \checkmark
 - (b) Tibetan High
 - (c) Icelandic Low
 - (d) Siberian Low

- (e) Aleutian Low
- 23. There is normally a convergence of surface air into the centre of a mid-latitude storm (Low). However high aloft above the storm, it is most common that there is _____
 - (a) Adiabatic compression
 - (b) Adiabatic expansion
 - (c) Subsidence
 - (d) Convergence
 - (e) Divergence \checkmark
- 24. Which of the following air properties would normally increase as you travelled upward through the summer, daytime Planetary Boundary Layer?
 - (a) air density
 - (b) air pressure
 - (c) air temperature
 - (d) wind speed \checkmark
 - (e) humidity
- 25. Which statement is untrue? The vapor pressure (e) and dewpoint temperature (T_d) of an air parcel _____
 - (a) are in 1:1 relationship (one implies the other)
 - (b) determine the relative humidity of the parcel \checkmark
 - (c) provide equivalent information
 - (d) are not independent of one another
 - (e) have different units
- 26. A "baroclinic" region of the atmosphere is a region where _____
 - (a) isotherms and height contours are parallel
 - (b) isotherms and height contours are not parallel \checkmark
 - (c) windspeed and pressure are related by the Geostrophic equation
 - (d) the Coriolis force vanishes
 - (e) the environmental lapse rate lies between the dry and moist adiabatic lapse rates
- 27. "Lee cyclogenesis" occurs
 - (a) at a land/sea boundary
 - (b) at an ice-sheet/sea boundary
 - (c) on a stationary polar front

- (d) downwind of a small island
- (e) downwind of a major mountain range \checkmark
- 28. Mid-latitude cyclones generally move faster _____
 - (a) in summer
 - (b) in winter \checkmark
 - (c) in the ITCZ
 - (d) than the winds at 500 mb
 - (e) than the Alberta Clipper

29. The "vault" observed on a radar image of a supercell thunderstorm corresponds to _____

- (a) the region of heaviest hailstones
- (b) the region of heaviest raindrops
- (c) the cold downdraft region
- (d) the entry region of the warm inflow \checkmark
- (e) the dome where the cloud protrudes into the stratosphere
- 30. Suppose the temperature and relative humidity (RH) of the air outside were 5 C, 50%, and that the air in your house consists simply of the same air, but heated to +20 C. The relative humidity in your house would be about _____
 - (a) 95%
 - (b) 50%
 - (c) 20% ✓
 - (d) 2%
 - (e) 0.2%
- 31. An elevated inversion separating warm, moist surface air from a deep layer of conditionally unstable air, is significant for severe weather because
 - (a) it can restrict convection early in the day
 - (b) it can result in isolated cumulonimbus, where exceptional thermals penetrate
 - (c) it is associated with cyclogenesis
 - (d) it is associated with a cold front
 - (e) both (a) and (b) are true \checkmark
- 32. When pure water freezes, the initial "clumps" of ice are called _____
 - (a) ice nuclei
 - (b) ice embryos \checkmark

- (c) ice proto-molecules
- (d) ice aerosols
- (e) freezing nuclei
- 33. Numerically, the dry adiabatic lapse rate (DALR, [C m⁻¹]) is determined by which two factors? (ρ, p are the density and pressure, $c_p \approx 10^3$ J kg⁻¹ K⁻¹ is the specific heat capacity at constant pressure, $g \approx 10$ m s⁻² is the gravitational acceleration.)
 - (a) c_p, ρ
 - (b) g, ρ
 - (c) g, p
 - (d) ρ, p
 - (e) $c_p, g \checkmark$
- 34. A sequence of grid points along a line of constant latitude are separated by constant intervals Δx and labelled by index *I*. Let the symbol T_{I-1} represent temperature at gridpoint I 1 (etc). Then $(T_{I+1} T_{I-1}) / (2\Delta x)$ represents _____
 - (a) the rate-of-change in time of temperature at gridpoint I
 - (b) the vertical temperature gradient [degrees per kilometre] at gridpoint I
 - (c) the north-south temperature gradient at gridpoint I
 - (d) the east-west temperature gradient at gridpoint I \checkmark
 - (e) the rate of temperature advection from gridpoint I-1 to gridpoint I+1
- 35. The "anvil" of a thunderstorm cloud signifies _____
 - (a) the Level of Free Convection (LFC)
 - (b) the Lifting Condensation Level (LCL)
 - (c) the existence of strong wind shear \checkmark
 - (d) the location of the warm updraft
 - (e) the location of the cold downdraft
- 36. The most important source of uncertainty in the response of earth's climate to increased atmospheric CO₂, as predicted by today's coupled ocean-atmosphere Global Climate Models, is believed to arise from _____
 - (a) inadequate resolution of topography on the computational grid
 - (b) imprecisely specified initial conditions
 - (c) inaccurate parametrization of the sea-air carbon flux
 - (d) oversimplified specification of the major ocean currents
 - (e) inaccurate simulation of cloud feedbacks, ie. uncertain response of global cloudiness \checkmark

- 37. The Coriolis parameter $f = 2\Omega \sin \phi$ (where Ω is the earth's rotation rate, and ϕ is latitude) has units _____ and is numerically equal to _____
 - (a) $m s^{-1}$; Coriolis force
 - (b) s; Coriolis force
 - (c) $m s^{-1}$; earth vorticity
 - (d) s⁻¹; earth vorticity \checkmark
 - (e) s; relative vorticity

38. The Last Glacial Maximum occurred about _____ kBP (ie. kiloyears Before Present)

- (a) 110
- (b) 21 ✓
- (c) 10
- (d) 5
- (e) 0.2
- 39. If global warming driven by increasing atmospheric CO_2 concentration results in less ice/snow cover, planetary albedo will be _____ which is an example of a _____ feedback
 - (a) increased; negative
 - (b) increased; positive
 - (c) decreased; negative
 - (d) decreased; positive \checkmark
 - (e) unaltered; fictitious
- 40. Wherever mountain peaks extend up to about 3 or more kilometers above sea-level, regional winds at the 700 mb level likely _____
 - (a) blow parallel to the height contours
 - (b) blow parallel to isotherms
 - (c) blow perpendicular to isotherms
 - (d) obey the Geostrophic equation
 - (e) do not obey the Geostrophic equation \checkmark

41. The highest level for which CMC synoptic analyses are available on the web is _____ mb

- (a) 100
- (b) 250 ✓
- (c) 300
- (d) 400
- (e) 500

- 42. Consider a level field of bare, dry soil. Over a cloudless summer day the maximum value of the hourly-averaged soil heat flux density Q_G is probably _____
 - (a) no larger than about 1370 W m^{-2}
 - (b) no larger than about 10 W m $^{-2}$
 - (c) about equal to net shortwave radiation K^*
 - (d) about equal to incoming shortwave radiation $K \downarrow$
 - (e) up to about 10 20 % of the net radiation Q^* 🗸
- 43. A deep (ie. order 1 kilometer) temperature inversion sometimes persists in winter over central Alberta because _____
 - (a) snow cover reflects the weak incoming solar energy flux of the short winter day
 - (b) continental airmasses at high latitude may experience net daily heat loss to the surface, itself cooling due to net radiative energy loss
 - (c) winds aloft may advect milder air over the cold surface air
 - (d) all of (a), (b) and (c) pertain \checkmark
 - (e) none of the above correctly explain the phenomenon
- 44. In regard to modern NWP models _____
 - (a) gridpoint spacing on the "mesh" is now fine enough to represent individual cumulus clouds and even the smallest of the microscale motions
 - (b) due to a uniformly dense global network of weather stations the problem of datasparsity has been overcome, and the accuracy of the initial state is not an issue
 - (c) all pertinent processes are adequately represented
 - (d) they solve exact (100% complete and perfect) mathematical statements of all the relevant laws
 - (e) the "prognostic charts" estimate the future state of the atmosphere as defined by values of pressure (or height), temperature (etc.) at all grid points \checkmark
- 45. Global warming due to increased atmospheric CO₂ concentration may result in changes in cloud coverage and type. "Cloud feedback" on global warming is known to be _____
 - (a) positive
 - (b) negative
 - (c) insignificant
 - (d) important, but of differing sign in differing GCM's \checkmark
 - (e) insensitive to assumptions about cloud microphysics
- 46. The forecasting technique that produces several forecasts for the same "valid at" time, all using the same NWP model, but each beginning with slightly different "present weather" so as to reflect errors in measurements, is called _____

- (a) climatology forecasting
- (b) probability forecasting
- (c) average forecasting
- (d) persistence forecasting
- (e) ensemble for ecasting \checkmark
- 47. The "cloud droplet size spectrum"
 - (a) is uniform (ie. constant) in the range $0.0001 1000 \,\mu\text{m}$
 - (b) is known as the "Bergeron" bell-shaped curve
 - (c) is impossible to measure
 - (d) can be measured by light-detector arrays sensing the particles' shadows in an artificial light beam \checkmark
 - (e) peaks at droplet size $d_{max} = \frac{2900}{T}$ where T is cloud temperature
- 48. L.F. Richardson wrote the following parody to illustrate the range of scales of atmospheric motion: "Big whorls have little whorls, Which feed on their velocity; And little whorls have lesser whorls, And so on to _____ "
 - (a) infinity
 - (b) capacity
 - (c) complexity
 - (d) stability
 - (e) viscosity \checkmark
- 49. If a layer of the atmosphere remote from ground became absolutely unstable, _____ would promptly return that layer towards _____
 - (a) spontaneous convective mixing; unconditionally stable stratification
 - (b) spontaneous convective mixing; neutral stability \checkmark
 - (c) molecular conduction; neutral stability
 - (d) molecular conduction; unconditionally stable stratification
 - (e) latent heat of condensation; an isothermal state
- 50. If a sample of air is saturated at 20 C, its absolute humidity is $___$ kg m⁻³
 - (a) $1.7 \ge 10^{-4}$
 - (b) $2.5 \ge 10^{-3}$
 - (c) $1.7 \ge 10^{-2}$ \checkmark
 - (d) $2.5 \ge 10^{-1}$
 - (e) 1.7

- 51. If the earth was a waterless planet
 - (a) the Bowen ratio would be zero
 - (b) daily near-surface temperature range would exceed true earth's \checkmark
 - (c) cumulonimbus would be a more common cloud type
 - (d) downward planetary radiation $L \downarrow = 0$
 - (e) convectively-driven windstorms would never occur

For the remaining questions, please refer to the attached charts (valid 12Z Dec 13, 2004).

- 52. The entry for pressure at the surface station nearest the centre of the Great Lakes low is 949. This is to be interpreted as _____
 - (a) station pressure is 949 mb
 - (b) sea-level corrected pressure is 949 mb
 - (c) station pressure is 994.9 mb
 - (d) sea-level corrected pressure is 994.9 mb \checkmark
 - (e) sea-level corrected pressure is 1094.9 mb
- 53. The isobar running through the point **A** should be labelled _____ mb
 - (a) 1016
 - (b) 1020
 - (c) 1024
 - (d) 1028
 - (e) 1032 ✓

54. From the evidence of the surface pressures this low will most likely track to the _____

- (a) north or northwest
- (b) west or southwest
- (c) south or southeast
- (d) east or northeast
- (e) uncertain, since all stations immediately encircling the low report rising pressure \checkmark

55. Stations nearest to the Great Lakes low are reporting _____

- (a) steady rain as present weather
- (b) steady rain as past weather
- (c) steady snow as present weather \checkmark
- (d) steady snow as past weather

(e) clearing skies at 12Z

- 56. The highest surface dewpoints in the vicinity of this low (ie. excluding stations near the coast or over the sea) are _____ the centre of lowest pressure
 - (a) north of
 - (b) northeast and east of
 - (c) southeast and south of
 - (d) west or northwest of
 - (e) right at \checkmark
- 57. Normally _____ should be highest at the centre of the low while _____ would more likely be severe to the NW, W and SW of the low, where the isobars are more tightly bunched and temperatures are lower.
 - (a) windspeed; windchill
 - (b) wind chill; snowfall rate
 - (c) snowfall rate; windchill \checkmark
 - (d) pressure; rainfall rate
 - (e) pressure; windchill

58. The dashed lines on the 850 mb chart are _____

- (a) height contours
- (b) thickness contours
- (c) vorticity contours
- (d) temperature contours \checkmark
- (e) freezing rain contours

59. At the centre of the 850 mb low the height of the 850 mb surface is _____

- (a) 112.5 dam
- (b) 12.5 km
- (c) 125 m
- (d) 125 dam ✓
- (e) 10.125 km

60. Reported winds at the 850 mb level are broadly _____ with the _____ model

- (a) consistent; lake-effect
- (b) inconsistent; lake-effect
- (c) consistent; Geostrophic \checkmark

- (d) inconsistent; Geostrophic
- (e) equivalent; anticlockwise
- 61. On the 850 mb chart we may identify occurrence of
 - (a) cold advection at \mathbf{b} , warm advection at \mathbf{c}
 - (b) warm advection at \mathbf{b} , cold advection at \mathbf{c}
 - (c) cold advection at both **b** and **c** and at neighboring regions to the east and west \checkmark
 - (d) warm advection at both ${\bf b}$ and ${\bf c}$
 - (e) a dryline along the Atlantic coast
- 62. A trough of low surface pressure extends west-southwestward from the centre of the low. On the basis of the available evidence this trough _____
 - (a) coincides (spatially) with a cold front
 - (b) coincides (spatially) with a warm front
 - (c) coincides (spatially) with a quasi-stationary front
 - (d) does not correspond to any distinct feature of the 850 mb temperature field \checkmark
 - (e) corresponds to a trough of cold air aloft
- 63. A well-defined region of strong _____ advection, providing a clue as to the probable direction of progress of the surface low, _____ be seen at 850 mb.
 - (a) cold; can \checkmark
 - (b) cold; cannot
 - (c) warm; can
 - (d) warm; cannot
 - (e) vorticity; can

64. The surface low (centred roughly at 45° lat., 80° long.) is _____ a 500 mb _____

- (a) co-located with; closed low \checkmark
- (b) co-located with; shortwave trough
- (c) co-located with; shortwave trough exit
- (d) co-located with; longwave ridge
- (e) upwind from; shortwave trough
- 65. The Great Lakes low is _____
 - (a) supported by warm advection aloft at 850 mb
 - (b) supported by cold advection aloft at 850 mb
 - (c) supported by probable convergence aloft at 500 mb

- (d) supported by warm advection at 850 mb and (probable) convergence at 500 mb
- (e) lacking any obvious upper support \checkmark
- 66. Surface temperature and dewpoint are higher (-7, -9 C) on the south shore of Lake Superior (see the station north of the marker **B**; the weather symbol = denotes 'mist') than north or west of the lake. It would be reasonable to speculate that _____
 - (a) this is just the normal north-south gradient expected at this latitude and time of year
 - (b) this station is in the warm sector of the Great Lakes low
 - (c) frictional convergence on the downwind shore has caused adiabatic warming
 - (d) Lake Superior is largely ice free \checkmark (note: the ice survey, not shown, confirmed this)
 - (e) Lake Superior is entirely iced over
- 67. The sounding is from International Falls (INL), just inside the U.S. near the south-eastern border of Manitoba (on the maps the code "INL" has been superposed just above the observations). Comparing the INL sounding with the corresponding data on the maps, there appears to be an inconsistency at the _____ level(s)
 - (a) 500 mb
 - (b) 850 mb
 - (c) surface \checkmark
 - (d) surface and 850 mb
 - (e) surface and 500 mb
- 68. The neutral layer below 900 mb at INL, where ELR \approx SALR, is consistent with _____
 - (a) clear skies and light winds overnight
 - (b) plentiful mixing overnight due to wind \checkmark
 - (c) rain freezing while falling through the layer
 - (d) snow melting while falling through the layer
 - (e) none of the above

69. The lowest inversion at INL has its base at _____

- (a) the surface
- (b) about 900 mb \checkmark
- (c) about 850 mb
- (d) about 800 mb
- (e) about 700 mb
- 70. The sounding at INL _____
 - (a) suggests freezing rain may soon occur

- (b) suggests heavy snowfall may soon occur
- (c) suggests there is convective cloud below about 800 mb
- (d) suggests there could not be stratiform cloud below about 850 mb
- (e) suggests precipitation, if it should occur, would be in the form of light snowfall \checkmark

Equations and Data.

 $\bullet \ Q^* = Q_H + Q_E + Q_G + Q_S$

The surface energy balance. All fluxes are in $[W m^{-2}]$. Q^* the net radiation, positive if directed towards the ground surface; Q_H, Q_E the sensible heat flux and the latent heat flux, positive if directed away from the ground surface; Q_G the soil heat flux, positive if directed away from the ground surface; Q_S , the storage term. The Bowen ratio $B = Q_H/Q_E$.

 $\bullet \ Q^* = \ K^* \ + L^* \ = K \downarrow - K \uparrow + L \downarrow - L \uparrow$

The surface radiation balance. All fluxes are in $[W m^{-2}]$. $K \downarrow, K \uparrow$, the incoming and outgoing solar fluxes (net solar, $K^* = K \downarrow -K \uparrow$); and $L \downarrow, L \uparrow$, the incoming and outgoing longwave fluxes (net longwave, $L^* = L \downarrow -L \uparrow$).

• $\Delta H = c_p \Delta T - \frac{1}{\rho} \Delta p$

The first law of thermodynamics, where $\Delta H [\text{J kg}^{-1}]$ is the heat added to the system, c_p is the specific heat capacity of the material at constant pressure ($c_p \approx 10^3 \text{ J kg}^{-1} \text{ K}^{-1}$ for air) and ρ is the density of the material.

• $e = \rho_v R_v T$

The ideal gas law for water vapor. e [Pascals], vapor pressure; ρ_v , $[kg \ m^{-3}]$ the absolute humidity (ie. vapor density); T [Kelvin], the temperature; and $R_v = 462$ [$J \ kg^{-1} \ K^{-1}$], the specific gas constant for water vapor).

• Each full slash on the wind barb counts 5 m s^{-1}

Table 1: Saturation vapour pressure $e_s(T)$ [mb] versus temperature T [C].

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



