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Department of Physics

Examination paper for FY3201 and FY8902 Atmospheric Physics and Climate Change (2019 VÅR)

Academic contact during examination: Patrick Espy

Phone: Office: 73 55 10 95 or Mobile: 41 38 65 78

Examination date: 27 May 2019

Examination time (from-to): 09:00-13:00

Permitted examination support material:

1-SIDE of A5 sheet with printed or handwritten formulas permitted

All calculators permitted

Single or bi-lingual dictionary permitted

Other information:

Students will find the examination results in Studentweb. Please contact the department if you have questions about your results. The Examinations Office will not be able to answer this.

Equation and Information sheet

You may take:

Molar mass of dry air: ~29 kg/kmole
Molar mass of helium: ~4 kg/kmole
Molar mass of H_2O: ~18 kg/kmole

$N_A = 6.02 \times 10^{23}$ molecules/mole Boltzmann's constant $k = 1.38 \times 10^{-23}$ J/K

273.15 K = 0 °C 1 hPa = 10^2 Pa = 10^2 N m^{-2} g=9.8 m s^{-2} and constant in z

Stefan–Boltzmann constant: $\sigma = 5.67 \times 10^{-8}$ W·m^{-2}·K^{-4}

Solar photospheric temperature, T_s = 5786 K Radius of the Sun = 695800 km

Radius of the Earth = 6370 km 1 AU (Earth-Sun distance) = 150×10^6 km

Latent heat of vaporization water: $L_v = 2.5 \times 10^6$ J· kg^{-1}

Latent heat of sublimation ice: $L_i = 2.8 \times 10^6$ J· kg^{-1}

Gas constant for water vapour: R_v=461 J·K^{-1}·kg^{-1}

Values for dry air: C_p=1004 J·K^{-1}·kg^{-1} C_v=718 J·K^{-1}·kg^{-1} R_d=287 J·K^{-1}·kg^{-1}

$\gamma = C_p / C_v$ $\kappa = R_d / C_p$ $R_d = C_p - C_v$ Γ_{da}=9.8 K/km

Clausius–Clapeyron relation: $e_s = 6.112\,hPa \cdot \exp\left[\frac{L_v}{R_v}\left(\frac{1}{273\,K} - \frac{1}{T}\right)\right]$

Answer all questions (English, Norwegian, or Swedish).
State all assumptions.
Good Luck!

1 Black Body Radiation (5%)

Sketch the spectral radiance (with intensity on the y-axis and wavelength on the x-axis) for three blackbodies at temperatures $T_1 > T_2 > T_3$. Label the curves with their temperatures and give the units used for the axes.

You can answer on your exam paper rather than on-line

Fill in your answer here

Format

Words: 0

Maximum marks: 5

2 Atmospheric Spectroscopy (5%)

Greenhouse gases absorb photons at specific wavelengths corresponding to the energy differences of the internal energy states of the molecule. However, there is a range of wavelengths about the line centre, ν_0, which can also absorb. Sketch the relative absorption coefficients, k_ν, for an absorption line at temperature T for both high and low pressures. For the x-axis, use $(\nu - \nu_0)/\alpha$, the distance from the line centre measured in line-widths, α. Label the two curves with the line shape type.

You may answer on your exam paper rather than on-line.
Fill in your answer here

Format

Words: 0

Maximum marks: 5

3 Atmospheric Stability (20%)

a. Assuming dry air explain what is meant by (1) a stable, (2) an unstable and (3) a neutrally stable atmosphere. (4%)

b. A meteorological balloon is required to take measurements up to an altitude where the pressure and temperature are 10 hPa and 225 K respectively. The balloon is constructed of a non-stretch material that remains slack (that is, not stretched tightly) until the balloon reaches its peak altitude and has expanded to its full spherical shape. If the balloon contains helium (molecular weight 4 $g \cdot mol^{-1}$), the payload weighs 100 kg and the fabric is of thickness 25 μm and density 1000 $kg \cdot m^{-3}$, what approximate radius of balloon is needed? (8%)

c. Assuming the mean temperature of 255 K between the surface, where the pressure is 1000 hPa, and the balloon altitude at 10 hPa, what is the altitude of the balloon in metres? (4%)

d. Assuming the atmosphere is stable with respect to vertical motion, estimate the temperature at the surface where the pressure is 1000 hPa. (4%)

You may answer on your exam paper rather than on-line

Fill in your answer here

Format

Words: 0

Maximum marks: 20

4 Atmospheric thermodynamics, water vapour and structure (20%)

a. Calculate the period of oscillation of an air parcel given that $dT/dz = -6.5\ \mathrm{K \cdot km^{-1}}$ and T=270 K. (6%)

b. Air at a temperature 20°C and pressure 1000hPa has a dew point of 15°C. What is (1) its relative humidity and (2) its water vapour mass mixing ratio? (6%)

c. Air initially at sea level with a temperature 20°C and dew point 15°C is forced to rise over a mountain of height 1000 m. What are the temperature, dew point and relative humidity of the air when it has sunk to a level 200m above sea level on the other side of the mountain? (assume no precipitation takes place). (8%)

You can answer on your exam paper rather than on-line

Fill in your answer here

Format

Words: 0

Maximum marks: 20

5 Atmospheric radiation (20%)

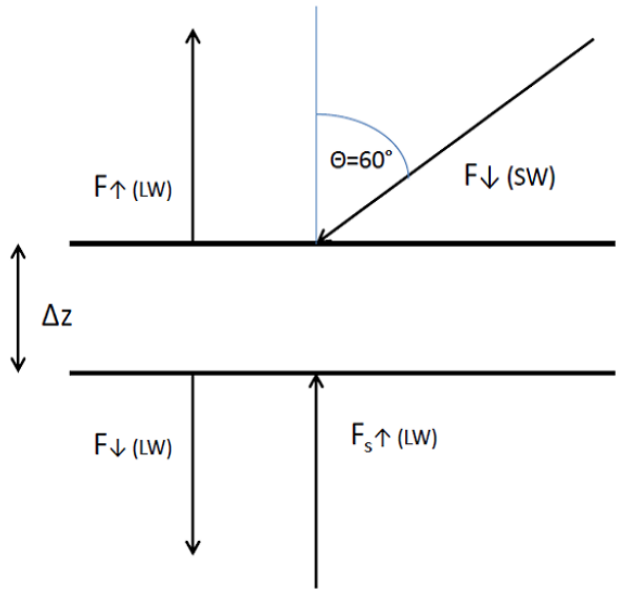
You can answer on your exam paper rather than on-line:

a. (4%)Define (that is give the units) and the connection between:
   1. Spectral radiance
   2. Radiance
   3. Irradiance

b. Mars has a radius of 3389.5 km and the distance to the sun is 1.524 AU (astronomical units). If its surface albedo is 0.250, calculate its radiative equilibrium temperature assuming no atmosphere. (6%)

c. The surface temperature of Mars is measured to be 242 K, what is the long-wavelength optical depth and transmission of the Martian atmosphere assuming the short-wavelength transmission is 1? (4%)

d. In the figure below, a layer in the atmosphere of thickness Δz and density ρ receives and emits radiation. The layer receives short-wavelength radiation $F\downarrow(SW)$ that is at a zenith angle of $\theta=60°$, and long-wavelength radiation $F_s(LW)$ from directly below. In the layer, the species that absorb short wavelength radiation have a mixing ration of $\nu_{abs}(SW)$ and a mass-absorption coefficient of $k_{abs}(SW)$. The mixing ratio of species that absorb long wavelength radiation have a mixing ratio of $\nu_{abs}(LW)$ and a mass-absorption coefficient $k_{abs}(LW)$. The flux of short wavelength radiation, $F\downarrow(SW)$, is given for a surface normal (90°) to the direction of the incoming radiation. Assuming the layer is in radiative equilibrium, calculate the temperature of the layer. (6%)



$\rho = 0.2\ kg \cdot m^{-3}$

$F\downarrow(SW) = 800\ W \cdot m^{-2}$

$k_{abs}(SW) = 100\ m^2 \cdot kg^{-1}$

$k_{abs}(LW) = 100\ m^2 \cdot kg^{-1}$

$\nu_{abs}(SW) = 1.0 \times 10^{-5}$

$\nu_{abs}(LW) = 3.0 \times 10^{-4}$

$\Delta z = 500\ m$

$F_s\uparrow(LW) = 200\ W \cdot m^{-2}$

Fill in your answer here

Format

Words: 0

Maximum marks: 20

i Multiple choice question instructions

The multiple choice questions 6-15 should be answered on-line

Select the best answer. 3 points for a correct answer, 0 for an incorrect or no answer.

6 Lapse rate (3%)

If an atmospheric lapse rate of 6 K/km is measured, which of the following is true?
Select one alternative:

- The temperature rises with altitude and the atmosphere is conditionally unstable
- The temperature rises with altitude and the atmosphere is absolutely stable
- The temperature falls with altitude and the atmosphere is conditionally unstable
- The temperature rises with altitude and the atmosphere is conditionally stable
- The temperature falls with altitude and the atmosphere is absolutely unstable

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Maximum marks: 3

7 Earth irradiance 3%

At which wavelength does the Earth's blackbody irradiance peak?
Select one alternative:

- ~150 nm
- ~1500 nm
- ~150000 nm
- ~15000 nm

Maximum marks: 3

8 Saturated absorption CO2 (3%)

If the atmospheric absorption of carbon dioxide at 15 μm becomes saturated, what happens if carbon dioxide levels continue to increase?
Select one alternative:

- Total absorption begins to decrease near the band centre after it saturates
- Total absorption stays the same because it is saturated
- The absorption continues to increase but only near the band centre
- None of the above
- Total absorption increases as lines farther from the band centre begin to saturate

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Maximum marks: 3

9 Albedo influence of ice caps (3%)

Describe the change in the Earth's visible albedo if the polar ice caps melt
Select one alternative:

- It will decrease
- It will first decrease and then increase
- It will not change
- It will increase
- None of the above
- It will first increase and then decrease

Maximum marks: 3

10 Ozone (3%)

In which layer of the atmosphere is ozone the ***major*** species?
Select one alternative:

- Troposphere
- None of the above
- Mesosphere
- Thermosphere
- Stratosphere

Maximum marks: 3

11 Droplet evaporation (3%)

A small cloud droplet will evaporate _____ a large cloud droplet?
Select one alternative:

- faster than
- more slowly than
- None of the above
- it will not evaporate
- at the same rate as

Maximum marks: 3

12 Stability (3%)

Which two atmospheric layers would the mean temperature profiles be stable against convection?
Select one alternative:

- Stratosphere and Thermosphere
- The atmosphere is never stable against convection
- Mesosphere and Stratosphere
- Stratosphere and Troposphere
- Mesosphere and Thermosphere

Maximum marks: 3

13 Coriolis (3%)

From what phenomenon does the Coriolis effect arise?
Select one alternative:

- Effect of winds high in the atmosphere
- None of the above.
- Rotation of the spherical Earth around the sun
- Curvature of the Earth's surface
- Rotation of the spherical Earth around its axis
- Motion of the oceans in their basins

Maximum marks: 3

14 Rainbow (3%)

In late afternoon at the Equator, in which direction would you look to find a rainbow?
Select one alternative:

- South
- East
- North
- Rainbows do not occur at the Equator
- West

Maximum marks: 3

15 Climate Sensitivity Factor (3%)

If no feedbacks are included, what would the climate sensitivity factor be for a ±1% change in solar irradiance?
Select one alternative:

- 36 ^{o}C per fractional change in solar irradiance
- -206 ^{o}C per fractional change in solar irradiance
- 72 ^{o}C per fractional change in solar irradiance
- -104 ^{o}C per fractional change in solar irradiance
- 206 ^{o}C per fractional change in solar irradiance
- -72 ^{o}C per fractional change in solar irradiance
- 104 ^{o}C per fractional change in solar irradiance

Maximum marks: 3