

PRINT Name: _____ Student Number: _____

You have 50 minutes to complete this exam, so pace yourself accordingly. Please be neat!!
Total possible points: 60

I. Multiple choice - 1 point each (check the appropriate box, **only one** is correct) [Total: 12 points].

1. Using satellite imagery it is possible to see the location of clouds 24 hours a day using:
 visible wavelengths
 infra-red wavelengths
 ultra-violet wavelengths
 shortwave
2. On a weather map the lines of equal pressure are called:
 isotherms
 isohyets
 isobars
 isotachs
3. Which of the following is the most abundant gas in the atmosphere:
 oxygen
 nitrogen
 water vapor
 carbon dioxide
4. On average, for every 1km increase in altitude in the troposphere, the air temperature
 remains unchanged
 increases 6.5 °C
 decreases 6.5 °C
 increases 65 °F
5. When water vapor condenses in the atmosphere
 clouds get dissolved and disappear
 latent heat of vaporization is released
 no energy conversion occurs
 latent heat of vaporization is taken up
6. The annual temperature range at most latitudes in the Southern Hemisphere is much smaller than that in the Northern Hemisphere. The reason for this is that:
 the Earth is closer to the Sun during the Southern Hemisphere summer
 less area is covered by desert in the Southern Hemisphere
 a greater proportion of the land surface is mountainous in the Southern Hemisphere
 there is a greater percentage of water surface in the Southern Hemisphere
7. Which of the following statements is false?
 Pressure decreases non-linearly with height
 Average sea level pressure is about 1013 mb
 The 500 mb level is at a lower elevation than the 850mb level
 The troposphere contains more air than the stratosphere

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8. Atmospheric pressure is caused by
- climate change
 - release of latent heat
 - the weight of the overlying air
 - energy from the Sun
9. The Greenhouse Effect is caused by
- a reduction in wind speed
 - solar radiation that is reflected to the surface
 - absorption and re-emission of longwave radiation in the atmosphere
 - longwave radiation that is reflected back to the surface by ozone
10. What are the S.I. (metric) units for expressing pressure
- in Hg
 - W m^{-2}
 - kPa
 - K
11. The primary factor that determines what type and how much radiation an object emits is:
- albedo
 - scatter and particle diameter
 - temperature
 - distance to the sun
12. The energy balance equation for the top of the atmosphere summarizes the energy exchange between Earth and space. Therefore,
- it consists of terms describing radiation, convection and conduction
 - it is always equal to zero
 - it contains only shortwave and longwave radiation terms
 - it is an excellent tool to estimate the Greenhouse Effect

II. True or False - 1 point each (circle either **T** for true or **F** for false) **[Total: 10 points]**

1. **T F** The most important greenhouse gas today is water vapor.
2. **T F** The stratopause is the coldest part of the atmosphere.
3. **T F** In Bloomington the sun is straight overhead at noon on June 21 each year.
4. **T F** The seasons are caused primarily by Earth's inclination on the ecliptic plane.
5. **T F** Blue sky is caused by the selective scattering of the shorter wavelengths of solar radiation in the atmosphere.
6. **T F** Among the different modes of heat transfer in the atmosphere, conduction is the least significant.
7. **T F** Ocean currents have an important role in maintaining a balanced climate by transporting heat from the polar regions towards the tropics.
8. **T F** Specific humidity is useful to express the moisture content of air, and relative humidity is useful to express the degree of humidity perceived by humans.
9. **T F** The global water cycle is tied to the global energy balance through uptake and release of latent heat during phase changes of water.
10. **T F** The dryer the air, the lower the dew point temperature.

III. Numerical Problems – Show all work

[Total: 15 points].

Relevant Equations and Constants:

Wien's Law	$I_{\max} = \frac{a}{T}$	I_{\max} wavelength of maximum emission (μm) T emission temperature (K) $a = 2897 \mu\text{m}\cdot\text{K}$
Stefan-Boltzmann Law	$F_{\text{tot}} = \epsilon \cdot \sigma \cdot T^4$	F_{tot} total irradiance ($\text{W}\cdot\text{m}^{-2}$) T emission temperature (K) ϵ emissivity $\sigma = 5.67 \times 10^{-8} \text{W}\cdot\text{m}^{-2}\cdot\text{K}^{-4}$
Radiation Balance	$Q^* = \underbrace{K \downarrow - K \uparrow}_{K^* = K \downarrow (1 - a)} + \underbrace{L \downarrow - L \uparrow}_{L^*}$	Q^* net radiation ($\text{W}\cdot\text{m}^{-2}$) $K \downarrow, \uparrow$ shortwave radiation in, reflected ($\text{W}\cdot\text{m}^{-2}$) $L \downarrow, \uparrow$ longwave radiation out, in ($\text{W}\cdot\text{m}^{-2}$) a albedo
Universal Gas Law	$P = r \cdot R \cdot T$	P pressure (Pa) r density ($\text{kg}\cdot\text{m}^{-3}$) R gas constant (air) = $287 \text{J}\cdot\text{kg}^{-1}\cdot\text{K}^{-1}$ T temperature (K)
Conversions	$K = ^\circ\text{C} + 273$ $\text{Pa} = 10^{-3} \text{kPa} = 10^{-2} \text{mb}$	<i>Temperature:</i> Celsius to Kelvin <i>Pressure:</i> Millibar to Pascal

1. You obtain the following measurements of humidity and temperature:

- vapor pressure: $e = 25 \text{ mb}$
- air temperature: $T = 25 \text{ }^\circ\text{C}$

From the vapor pressure curve you obtain the following:

- saturation vapor pressure at $21 \text{ }^\circ\text{C}$: $e_s(21 \text{ }^\circ\text{C}) = 25 \text{ mb}$
- saturation vapor pressure at $25 \text{ }^\circ\text{C}$: $e_s(25 \text{ }^\circ\text{C}) = 30 \text{ mb}$

From these data, derive the following quantities:

(a) Relative Humidity (RH) [2 pts]

(b) Dew Point Temperature (T_d) [2 pts]2. The air inside a balloon has a volume of 0.05 m^3 , a temperature of 25°C and a density of 1.187 kg/m^3 . What is the pressure in the balloon? [2 pts]

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3. A grass surface has a temperature of $18\text{ }^{\circ}\text{C}$ and an emissivity of 0.96.

(a) How much radiation is the grass emitting (in $\text{W}\cdot\text{m}^{-2}$) ? [2 pts]

(b) At what wavelength is the grass emitting its maximum amount of radiation ? [1 pts]

4. Measurements were made by G109 Students in Bloomington on Sept 21 above Dunn Meadow. The incoming shortwave radiation was $850\text{ W}\cdot\text{m}^{-2}$, the albedo for the grass was 0.27, the surface temperature was $27\text{ }^{\circ}\text{C}$, and the grass had an emissivity of 0.90. The sky temperature was $-55\text{ }^{\circ}\text{C}$ with an emissivity of 0.98.

(a) What was the net shortwave radiation at this site ? [2 pts]

(b) What was the net longwave radiation? [3 pts]

(c) What was the net allwave radiation at this site ? [1 pts]

IV. Fill in the Blank and Short Answers

[Total: 23 points].

Please answer all questions as *clearly* as possible. Feel free to add diagrams and equations to help your explanations. You may use the back of the page, if necessary.

1. Recently, Ozone has been depleted in a layer of the atmosphere called the _____.[1 pts]

Why is the continued presence of Ozone in this layer of the atmosphere important ? [2 pts]

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2. Recently, Ozone increased in a layer of the atmosphere called the _____. [1 pts]
Why is the increasing concentration of Ozone in this layer of the atmosphere a concern ? [2 pts]
3. The amount of solar radiation flux received on a surface perpendicular to the radiation at the top of the atmosphere called the _____. [1 pts]
Why is the amount of solar radiation flux received at Earth's surface always less than that ? (Hint: there are two main reasons) [4 pts]
4. Are air temperatures more likely to be warmer on a *clear* or on a *cloudy* night? _____ [1 pts]
Why [2 pts]
5. The _____ is often nicknamed the *weather layer*. [1 pts]
Why is this nickname justified? [2 pts]
6. The process that occurs when water changes from its gaseous state to its liquid state is called _____, and is characterized by the release of _____. The reverse process is called _____. [3 pts]
7. *Relative humidity* is dependent on temperature. At a given water vapor content, if temperature goes *up*, relative humidity goes _____. [1 pts]

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Given the above, explain why *specific humidity* is called a *conservative* measure of humidity and relative humidity is not.

[2 pts]