

PRINT Name: _____ Student Number: _____

You have 50 minutes to complete this exam, so pace yourself accordingly. Please be neat!!

Total possible points: 70

I. Multiple choice - 1 point each (check the appropriate box, **only one** is correct) [Total: 15 points].

1. If an imbalance occurs between incoming and outgoing energy at the Earth's surface,
 - minimum temperatures occur
 - maximum temperatures occur
 - temperatures either increase or decrease
 - temperatures remain constant

2. On a temperature distribution map with lines of equal temperature (isotherms), the temperature gradient is greatest:
 - where the isotherms are closest together
 - where the isotherms are vertical
 - where the temperature is highest
 - near the coast

3. Which of the following is the most abundant variable 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 droplets evaporate in the atmosphere
 - clouds appear and it starts to rain
 - latent heat of vaporization is released
 - no energy conversion occurs
 - latent heat of vaporization is taken up

6. The atmosphere is heated primarily by:
 - absorption of solar radiation
 - conduction from the ground
 - absorption of terrestrial radiation
 - the depletion of ozone in the stratosphere

7. Which of the following statements is correct?
 - Pressure decreases non-linearly with height
 - Average sea level pressure is about 1013 kPa
 - The 500 mb level is at a lower elevation than the 850mb level
 - Pressure at a given level is equivalent to the weight of air below this level

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8. The Stefan-Boltzmann law

- is only valid for shortwave radiation
- is an expression of the conservation of energy
- is used to calculate total emitted radiation
- explains why the sky appears blue

9. The Greenhouse Effect is caused by

- a reduction in wind speed
- solar radiation that is reflected by 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 an energy flux?

- J·m
- 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 amount of solar radiation that reaches Earth's surface at a given place and time varies primarily with

- the latitude
- the surface energy balance
- the time of day
- the solar altitude

13. Earth is closest to the sun during

- southern hemisphere winter
- southern hemisphere summer
- northern hemisphere summer
- northern and southern hemisphere summer

14. In the Earth-atmosphere system, energy transfer by conduction is only relevant

- at night
- to warm the air
- to evaporate water
- to warm the ground

15. Air may best be described as

- an element
- a compound
- a mixture
- a molecule

II. True or False - 1 point each (circle either **T** for true or **F** for false) **[Total: 15 points]**

1. **T** **F** The most important greenhouse gas today is ozone.
2. **T** **F** The stratopause is the coldest part of the atmosphere.
3. **T** **F** Temperature in the stratosphere increases with height because of scatter of longwave radiation.
4. **T** **F** In Bloomington the sun's altitude is highest at noon on June 21 each year.
5. **T** **F** Over the course of a year, the length of day varies most at the poles.
6. **T** **F** Over the course of a year, the length of day stays the same at the equator.
7. **T** **F** The seasons are caused primarily by Earth's inclination on the ecliptic plane.
8. **T** **F** White clouds are caused by the selective scattering of the shorter wavelengths of solar radiation in the atmosphere.
9. **T** **F** Among the different modes of heat transfer, radiation is the only one that works between the sun and the Earth.
10. **T** **F** Ocean currents have an important role in maintaining a balanced climate by transporting heat from the tropics towards polar regions.
11. **T** **F** Energy is created by the sun and destroyed by ozone.
12. **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.
13. **T** **F** Climate relates to weather, as an individual relates to a population.
14. **T** **F** The importance of carbon dioxide in the atmosphere is solely due to its absorption and release of latent heat.
15. **T** **F** Temperature does not always decrease with height, but pressure always does.

III. Fill in the Blank**[Total: 24 points].**

Fill in the missing terms on the lines provided. **Broken lines** indicate that more than one word is needed. A prefix or suffix with a hyphen (e.g. "re-____" for "re-emit" or "re-flect") gives you a hint to what is needed

1. Over the last 30 years Ozone has been depleted in a layer of the atmosphere called the _____, characterized by _____ temperature with height. [2 pts]
The continued presence of Ozone in this layer of the atmosphere is important because Ozone reduces the amount of harmful _____ by _____ it. [2 pts]
2. Over the same period of time Ozone increased in a layer of the atmosphere called the _____. [1 pts]
The increasing concentration of Ozone in this layer of the atmosphere is of concern, because Ozone is a strong _____ with negative implications on human health. [1 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]
The amount of solar radiation flux received at Earth's surface always less than that due to processes called _____ and _____. [2 pts]
4. A closed cloud cover has the effect that the surface temperature is _____ during the day, because _____ radiation is _____ by it. [3 pts]
At night, clouds _____ the surface temperature, because _____-wave radiation emitted by _____ is _____ by clouds and then re-_____ back to _____. [6 pts]
5. The _____ is the coldest layer of the atmosphere. [1 pts]
It lies above the _____ and the boundary between them is called the _____. [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]

IV. Numerical Problems – Show all work

[Total: 16 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 ($\text{W}\cdot\text{m}^{-2}$) $K\downarrow, ?$ shortwave radiation in, reflected ($\text{W}\cdot\text{m}^{-2}$) $L\downarrow, ?$ longwave radiation out, in ($\text{W}\cdot\text{m}^{-2}$) a albedo
Universal Gas Law	$P = \rho \cdot R \cdot T$	P pressure ($\text{Pa} = \text{J}\cdot\text{m}^{-3}$) ρ 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	$\text{K} = ^\circ\text{C} + 273$ $\text{Pa} = 10^{-3} \text{kPa} = 10^{-2} \text{mb}$	<i>Temperature:</i> Celsius to Kelvin <i>Pressure:</i> Millibar to Pascal

1. The maximum radiation output of the sun is in the green color range, at a wavelength of $\lambda_{\max} = 0.5 \mu\text{m}$. Based on this information the sun's emission temperature can be computed.

(a) The name of the relevant equation here is _____ [1 pts]

(b) Given the above, the sun's emission temperature is computed as follows (in K):

_____ [2 pts]

2. The air inside a balloon has a volume of 0.05m^3 , a pressure of 1000 mb and a temperature of 25°C . The density of the air in the balloon is then defined and can be calculated.

(a) The name of the relevant equation here is _____ [1 pts]

(b) Given the above, the density of the air in the balloon is computed as follows (in $\text{kg}\cdot\text{m}^{-3}$):

_____ [2 pts]

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4. Measurements were made by G109 Students in Bloomington on Feb. 14 above Dunn Meadow. The surface temperature was 5 °C, and the grass had an emissivity of 0.90. The sky temperature was 2 °C with an emissivity of 0.98.

(a) The relevant equation to compute the outgoing longwave radiation is called:
_____ [1 pts]

(b) What was the outgoing longwave radiation at this site (in $W \cdot m^{-2}$)? [2 pts]

(c) What is the incoming longwave radiation at this site (in $W \cdot m^{-2}$)? [2 pts]

(d) What was the net longwave radiation at this site (in $W \cdot m^{-2}$)? [2 pts]

(e) Based on the above computations, is the surface gaining or losing longwave radiation at this site ?
The surface is _____ longwave radiation [1 pts]

(f) Which components of the surface energy balance would need to be measured, to calculate the albedo of the surface?
_____ and _____ [2 pts]