Course objectives: Our goal is to gain a deeper understanding of the:
1. Earth’s radiation balance
2. Structure of the atmosphere and its interaction with solar and terrestrial radiation.
3. Characteristics of molecules, water, and particles in the atmosphere and their interaction with each other and with other atmospheric constituents.
4. International scientific problems of global warming and ozone depletion, including the way that scientific research is translated into common understanding.

We will do this through laboratory exercises, demonstrations, calculations, discussions, and writing. Homework will be assigned and graded. Homework plus class participation will form the basis for your evaluation.

Notes:
1) Course materials will include copies of lecture notes/presentations, and in class notes. Reference material will be mentioned and some made available. There is no text available which covers the material at the appropriate level.
2) Your performance will be evaluated from the daily assignments and class participation. Jim McClurg and I will average our respective evaluations for your overall course grade.
3) The emphasis throughout the course will be on understanding, and that is what I will be looking for in the written assignments. If in the written assignments, I don't see that understanding demonstrated, I will evaluate accordingly. If appropriate you may have a chance to improve your Home work discussions on selected assignments.
4) Throughout the course I will also be mentioning the science activities I am involved in. Most of these will be related to what is pressing me at the moment, but there will be some mention of previous activities required of me. I do this in the hopes that it will give you a little more insight into what the life of a scientist is like.
Overview

1) June 11, 10:45-12:00, PS 132  - **Introduction**
   Course objectives, Linear/log relationships

2) June 11, 1:30-3:00 PS 132: **Radiation I**
   a) Intensity of radiation and distance (lab).
   b) Intensity of radiation and temperature of emitter (Stefan Boltzmann law) (lab).

3) June 12, 8-11:00, PS 132  **Radiation II**
   a) Planetary equilibrium temperatures and how to calculate them.
   b) Electromagnetic spectrum
   c) Black body radiation – black body curves, temperature and wavelength of peak emission
   d) Molecular absorption/emission of radiation

4) June 18, 1:30 – 3:00 EN 6085 **Objects in the sky I - molecules**
   Physics of the air above, and behavior of air pressure/temperature as a function of altitude.

5) June 19, 1:30-3:00, EN 6085 **Interaction of solar radiation with earth’s atmosphere I – molecules, particles**
   Atmospheric optics - scattering/refraction of light – blue sky, white clouds, sunsets, rainbows, haloes/sun dogs, mirages

6 a) June 20, 8-9:45, EN 6085 **Interaction of solar radiation with earth’s atmosphere II - atmospheric motion (winds)**
   Distribution of radiation, global heat balance, global circulation

6 b) June 20, 10:00-11:30, EN 6085 **Objects in the sky II – particles and water – Troposphere – clouds and rain/snow.**
   Vapor pressure, evaporation, condensation, phase changes, precipitation, latent heat

7 a) June 21: 8:00 – 9:45, EN 6085 **Objects in the sky III – particles and ozone - Stratosphere – Global Environmental issues I (ozone loss).**

7 b) June 21: 10:00-11:30, EN 6085 **Objects in the sky IV – carbon dioxide- Global Environmental issues II (global climate change)**

8) June 22, 1:30-3:00, EN 6085 - **Open for: Catch up / suggestions / questions**
   Review and summary, outstanding questions, ???
1) June 11, 10:45-12:00, PS 132

**Introduction** –

Why Science?
What is considered science?

Course goals
Understanding through inquiry (analysis, experiments, demonstrations, discussions) processes which occur in the atmosphere and which are often directly observable and/or directly affect our lives. We will work on developing the understanding and the language to discuss these phenomenon in a scientifically credible way. These goals are directly related to the following science content in Earth, Space and Physical Systems as specified by the Wyoming State Board of Education.

WYOMING STATE BOARD OF EDUCATION – Excerpts from: *Wyoming Science Content and Performance Standards Adopted July 7, 2003*

**EARTH, SPACE, AND PHYSICAL SYSTEMS Grades 9-12 Concepts and processes:**

7. **Geochemical Cycles:** Students describe the Earth as a closed system and demonstrate a conceptual understanding of the following systems: geosphere, hydrosphere, atmosphere, and biosphere. Students explain the role of energy in each of these systems, such as weather patterns, global climate, weathering, and plate tectonics.

11. **Chemical Reactions:** Students recognize that chemical reactions take place all around us. They realize that chemical reactions may release or consume energy, occur at different rates, and result in the formation of different substances. They identify the factors that affect reaction rates.

13. **Energy and Matter:** Students demonstrate an understanding of types of energy, energy transfer and transformations, and the relationship between energy and matter.

14. **Force and Motion:** Students develop a conceptual understanding of Newton's Laws of Motion, gravity, electricity, and magnetism.

**EARTH, SPACE, AND PHYSICAL SCIENCE – Grades 5-8, Concepts and processes.**

7. **The Earth in the Solar System:** Students describe Earth as the third planet in the Solar System and understand the effects of the sun as a major source of energy, gravitational forces, and motions of objects in the Solar System.

10. **The Structure and Properties of Matter:** Students identify characteristic properties of matter such as density, solubility, and boiling point and understand that elements are the basic components of matter.

11. **Physical and Chemical Changes in Matter:** Students evaluate chemical and physical changes, recognizing that chemical change forms compounds with different properties and that physical change alters the appearance but not the composition of a substance.

12. **Forms and Uses of Energy:** Students investigate energy as a property of substances in a variety of forms with a range of uses.

HISTORY AND NATURE OF SCIENCE IN PERSONAL AND SOCIAL DECISIONS - Students recognize the nature of science, its history, and its connections to personal, social, economic, and political decisions. - GRADE 8
1. Students explore the nature and history of science.
   A. Students explore how scientific knowledge changes and grows over time, and
      impacts personal and social decisions.
   B. Students explore the historical use of scientific information to make personal and
      social decisions.

2. Students explore how scientific information is used to make decisions.
   A. The role of science in solving personal, local, and national problems
   B. Interdisciplinary connections of the sciences and connections to other subject areas
      and careers in science or technical fields

EARTH, SPACE, AND PHYSICAL SYSTEMS - GRADE 4

4. **Properties of Earth Materials**: Students investigate water, air, rocks, and soils to
   compare basic properties of earth materials.

5. **Objects in the Sky**: Students describe observable objects in the sky and their patterns
   of movement.

6. **Changes in Earth and Sky**: Students describe observable changes in earth and sky,
   including rapid and gradual changes to the earth's surface, and daily and seasonal
   changes in the weather.

7. **Properties of Objects**: Students classify objects by properties that can be observed,
   measured, and recorded, including color, shape, size, weight, volume, texture, and
   temperature.

8. **Changes in States of Matter**: Students demonstrate that the processes of heating and
   cooling can change matter from one state to another.

9. **Physical Phenomena**: Students investigate physical phenomena commonly
   encountered in daily life, including light, heat, electricity, sound, and magnetism.

3. HISTORY AND NATURE OF SCIENCE IN PERSONAL AND SOCIAL
   DECISIONS - GRADE 4

1. Students recognize the nature and history of science.
   A. Discuss how scientific ideas change over time
   B. Describe contributions of scientists

2. Students recognize how scientific information is used to make decisions.
   A. Identify and describe local science issues, such as environmental hazards or
      resource management
   B. Suggest feasible solutions and personal action plans to address an identified issue

----------- End of excerpts Wyoming Science Content and Performance Standards

**Discussion of:**

1) Linear equation \( y = mx + b \), or if \( b=0 \), \( y=m \cdot x \)

2) Log transformation to convert a power law relationship to a linear equation. \( y = x^m \)
   can be converted to \( \log_{10}(y) = m \cdot \log_{10}(x) \)

3) Linear/linear versus log/log plotting
2) June 11, 1:30-3:00 PS 132: **Radiation I**

**Goals:** Explore relationship between a) Intensity of radiation and distance, and b) Intensity of radiation and temperature of emitter (Stefan Boltzmann law). Radiation source = 60 watt light bulb controlled by variac to adjust the voltage to the bulb. Intensity measured with photovoltaic cell connected to electrometer.

**Experiments:** Measure the intensity of radiation at 20, 40, and 80 cm using variac settings of 50, 70, 90 and 110 volts, corresponding to light bulb temperatures of 1700, 2200, 2600, and 3000 K.

**Home work:** Plot your lab data on linear and logarithmic paper (samples attached). Using lab data on intensity (I) versus temperature (T) and intensity versus distance (r) calculate the exponent in the experimental relationships, I \( \propto T^x \) and I \( \propto r^y \), where x and y are unknown, and \( \propto \) means "is proportional to".

<table>
<thead>
<tr>
<th>Voltage (Variac)</th>
<th>Temperature (K)</th>
<th>Distance (cm)</th>
<th>Averaged Intensity</th>
<th>Measured intensities</th>
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3) June 12, 8-11:00, PS 132  **Radiation II**

**Goals:** To understand -
   e) Planetary equilibrium temperatures and how to calculate them.
   f) Electromagnetic spectrum
   g) Black body radiation – black body curves, relation between temperature and wavelength of peak emission, Wien's law, \( \lambda = \alpha / T \), where \( \alpha = 2898 \, \mu \text{m/K} \)
   h) Molecular absorption/emission of radiation

**Vocabulary:** electromagnetic spectrum, black body radiation, temperature, wavelength, frequency, constructive/destructive interference, diffraction, emission, absorption solar/terrestrial absorbers, ozone, carbon dioxide, greenhouse gases

Demonstrate, discuss, measure - Visible light waves (Double slit / diffraction grating experiment) Frequencies/Colors, soap bubbles, (Prisms/diffraction gratings, spectrometers)

**Home work:** 3 a) Calculate planetary equilibrium temperatures using: a) \( I \propto 1/r^2 \), b) Stefan Boltzmann law, and c) sun-planet geometry, for Venus, Earth, and Mars. The radius of the sun is \( 7 \times 10^5 \) km and its temperature is 5800 K. Compare these temperatures with measured temperatures. Discuss differences. Given stellar temperatures of 3,000, 9,000 and 15,000 K at what distance from their sun would planets hospitable to life be found?

<table>
<thead>
<tr>
<th>Planet</th>
<th>Distance from sun (km)</th>
<th>Albedo</th>
<th>Temperatur e (K) - calculated</th>
<th>Temperatur e (K) - Measured</th>
<th>Relative to Earth</th>
<th>Mixing ratio (parts)</th>
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<tr>
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<td></td>
<td></td>
<td></td>
<td>CO₂</td>
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<tr>
<td>Venus</td>
<td>1.08 x 10⁸</td>
<td>0.75</td>
<td>0.95</td>
<td>0.82</td>
<td>90</td>
<td>.96</td>
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<tr>
<td>Earth</td>
<td>1.50 x 10⁹</td>
<td>0.31</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>.03</td>
</tr>
<tr>
<td>Mars</td>
<td>2.28 x 10⁹</td>
<td>0.29</td>
<td>0.53</td>
<td>0.11</td>
<td>0.05</td>
<td>.95</td>
</tr>
</tbody>
</table>
3 b) **Home work:** Use lab data to calculate the wavelength of light.

\[ h \sin(\theta) = n\lambda \rightarrow h*y/d = n\lambda \]
3 c) **Home work**: Using the sun/earth mean measured temperatures calculate the wavelength for peak radiation from these bodies.

**Black Body Curves**

**Maxwell's Rainbow**

![Graph showing the spectrum of electromagnetic waves from gamma rays to radio waves.](image-url)
3 d) **Radiation III - Interaction of solar and terrestrial radiation with earth’s atmosphere - molecules**

**Goals:** Gain an understanding of absorption/emission of radiation:

- a) Solar absorbers - UV absorption by ozone → Ozone hole
- b) Terrestrial absorbers – Water, Carbon Dioxide → Global climate change
- c) How the atmosphere changes the earth’s equilibrium temperature
- d) Atmospheric window
- e) Greenhouse gases (CO₂), Greenhouse warming
- f) Global climate change

**Demonstrations:** Continuum and discrete emission lines. Dependence of emission lines on emitting gas. Identification of gases by emission lines. (Use of plastic spectrometers - Franuhoffer lines, mercury lines)

**Home work:** Describe how the atmosphere influences the earth’s equilibrium mean temperature. Which gases are primarily involved? What radiation is involved? What happens to this radiation?
What altitude is this?
4) June 18, 1:30 – 3:00 EN 6085 Objects in the sky I - molecules

Goals: Gain an understanding of the physics of the air above, and behavior of air pressure/temperature as a function of altitude.

Vocabulary: Atmospheric pressure, ideal gas law, temperature, troposphere, stratosphere, convection.

Demonstrations: Atmospheric pressure (water barometer), Ideal gas law (expansion/contraction)

Home work: a) Explain how a straw works. b) Early miners could only descend about 30 ft below the water table before they could not keep the mine dry. Why is that?

Analysis of temperature profile: Troposphere - Convection, Stratosphere - Stability, Aerosol particles - Volcanic record

Home work: d) Plot temperature/pressure profile from atmospheric measurements. Plot the pressure using both linear-linear and log-linear graph paper. e) Calculate temperature lapse rate in the troposphere. f) Identify the tropopause (the boundary between troposphere and stratosphere). g) Describe the differences between the temperature profile in the troposphere and stratosphere. Include an explanation of what leads to these differences, and how these differences affect convection.

<table>
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<tr>
<th>Press. mbar</th>
<th>Altitude km</th>
<th>Temperature °C</th>
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<tr>
<td>781</td>
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<td>753.2</td>
<td>2.5</td>
<td>15</td>
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<td>710.2</td>
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<td>554.9</td>
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</table>
5) June 19, 1:30-3:00, EN 6085 **Interaction of solar radiation with earth’s atmosphere I – molecules, particles**

**Goals:** Gain an appreciation for atmospheric optics - scattering/refraction of light –
   a) Blue sky
   b) White clouds
   c) Sunsets
   d) Rainbows
   e) Haloes/Sun dogs
   f) Mirages

**Vocabulary:** Scattering (Rayleigh, Mie), refraction, diffraction, reflection, backscatter, sidescatter, forwardscatter

**Demonstrations:** Particle scattering angular dependence (sunbeams), Reddening of light, Refraction by ice crystals, Diffraction

**Home work:** Explain why clouds are white, the sky is blue and sunsets are red. Explain the formation of a less common optical phenomenon occurring in the sky. How would you expect the sky on Mars and Venus to appear? Provide a possible explanation for your conclusion.
Interaction of solar radiation with earth’s atmosphere
II - atmospheric motion (winds)

Goals: Understand the distribution of radiation across the earth. Understand how the impact of this differential heating and the earth’s rotation affect the global heat balance and how this controls:
Global circulation
  Prevailing westerlies
  Jet Streams
  Eddies/cyclones
  Easterly trade winds -> ENSO

Vocabulary: Differential heating, energy distribution per unit area, frames of reference, Coriolis force, westerlies, jet streams, cyclones, trade winds, ENSO, convection, pressure gradient force, air density


Home work: Describe the formation of prevailing mid-latitude upper-level westerly winds in both hemispheres. Begin with a discussion of why the distribution of solar radiation across the earth leads to temperature differences and thus a pressure gradient. It may be helpful to roughly draw an altitude latitude diagram illustrating the distribution of pressure from the equator to the poles.
6 b) June 20, 10:00-11:30, EN 6085 Objects in the sky II – particles and water – Troposphere – clouds and rain/snow.

**Goals:** To understand – vapor pressure, evaporation, condensation, the role of particles in phase changes, the processes of cloud and precipitation formation, the role of latent heat.

**Vocabulary:** vapor pressure, evaporation, condensation, latent heat, cloud condensation nuclei, ice nuclei

**Demonstrations:** Phase changes, boiling, boiling nuclei, condensation, condensation nuclei, cloud formation, ice formation.

**Home work:** Describe how water can exist in all three phases at one place in the sky (Note that the triple point does not occur in the sky). Which two phases can be seen? How do you tell the difference visually between these two phases? Why is the difference observable?
Goals: To understand the processes leading to ozone depletion:
  - Release of CFCs - global distribution
  - CFCs and UV radiation
  - ClO + O3 -> O2

Vocabulary: Ozone, UV radiation, Polar stratospheric clouds, chlorofluorocarbon (CFC), free radical, catalytic reaction, heterogeneous chemistry.

Home work: Describe why ozone depletion only occurs in the polar regions.

Supplementary material compliments of NOAA, WMO, EU, UNEP, NASA
Twenty Questions and Answers about the Ozone Layer: 2006 Update, David Fahey

This document is also available at

And a poster at:
http://www.esrl.noaa.gov/csd/assessments/2006/twentyquestionsposter.html
7) June 21: 10:00-11:30, EN 6085  **Objects in the sky IV – carbon dioxide- Global Environmental Issues II - Global Climate Change** (http://www-das.uwyo.edu/~deshler/Beamer/desh_beamer.html)

**Goals:** To understand the sources, processes, and potential impacts of the ubiquitous worldwide releases of CO₂ into the atmosphere. To understand the processes involved in scientific assessments, and how scientific expertise is used. Understand what future climate projections are based on.

**Vocabulary:** Combustion (oxidation), molecular weights, mixing ratio, infrared absorption, global climate models, scientific assessments, scientific uncertainty.

**Intergovernmental Panel on Climate Change – the following documents are available:**

Frequently asked questions  

Summary for Policymakers  

Technical report  

Other related documents at:  
http://ipcc-wg1.ucar.edu/wg1/wg1-report.html

8) June 22, 1:30-3:00, EN 6085 - **Open for: Catch up / suggestions / questions**
   Review and summary, outstanding questions, ???
   Measurement uncertainties, fringe/formal science, scientific research and public policy, ...