**AOS/IES 171 - Prof. Hitchman**

**Study Guide for 1st Mid-Term**

The format will be short answer, fill in the blank, matching, and multiple choice. The material will be based on my lectures through ENSO and NAM. Test questions will be formulated from material in this study guide.

**1. Evolution of the earth system**

Our sun's output four billion years ago was 25% weaker than at present. What could account for the planet not having been a frozen ice ball?

How is the earth's protective magnetic field generated?
Where does ozone come from?

How did the ozone layer help life to colonize the land?

Where is most of the ozone?

How thick is the ozone layer?
What are the approximate relative masses of the atmosphere, hydrosphere and lithosphere?

How did the present atmosphere come into being?

Compare the gases that come out of volcanoes with the mixture of air that we breathe. How can the discrepancies be resolved?
Describe the photosynthesis - oxidation equation in words.

During the northern summer does atmospheric CO2 concentration rise or fall?

How about during northern winter? Why?
During the last ice age were atmospheric CO2 and CH4 concentrations higher or lower than at present?

What relationship between these gases and temperature are found in the ice core record?

What might explain this relationship?

What might this relationship imply for the next few centuries?

**2. Population.** Contrast exponential growth and linear growth.

What does doubling time mean?

**3. Heating the earth.**

Where does almost all of the energy available on the earth's surface ultimately come from?
What does temperature measure?
Sketch the global average vertical temperature profile of the earth's atmosphere.

What are the names of each layer?

What accounts for the three temperature maxima?

Is there a constant output of radiant energy from the sun or is it variable?

**4. Units.** What are the “System Internationale” (SI) units for mass, length, time and temperature?

What are they for pressure, density, energy, power, and rate of transfer of electromagnetic radiation?
Express the freezing temperature of water and global average surface temperature in $°$F, $°$C and Kelvins.

What does 103 kg m-3 mean?

**5. Pressure and density.**

How high up into our atmosphere do you have to go to put 1/2 of the molecules below you?

At that level, what are the values of pressure and density?
At that level, is the temperature colder or warmer than at the surface?
What balances the force of gravity to keep air parcels from accelerating toward the center of the earth?
How dense are the ocean, human beings, and rocks?
How far down in the ocean do you have to go to add another 1 atmosphere of pressure?

**6. Electromagnetic spectrum and radiative transfer.**

What is the relationship between temperature and the wavelength of emitted electromagnetic radiation?
What are short wave and long wave radiation?
How hot is the photosphere of the sun?

How hot is the earth's surface?
How long is one micrometer (1 $μm$)?
What does the Stefan-Boltzmann law imply about the relationship between temperature and the amount of electromagnetic energy coming from a body?
How does the intensity of electromagnetic radiation decrease away from a source?
Which photons are the most energetic?

What wavelengths are typically emitted from the sun?

Which wavelengths carry most of the energy from the sun?
What wavelengths are typically reflected from the earth?

What wavelengths are typically reflected from the moon?
What wavelengths are typically emitted from the earth's surface and from greenhouse gas molecules in the atmosphere?
What does transparent mean?
What does absorb and re-emit mean?
Which parts of the electromagnetic spectrum are most relevant to the ozone problem, and which to the greenhouse problem?

**7. Heat budget of the earth and the atmospheric greenhouse effect.**

What is radiative equilibrium?
What is albedo?

What is the typical albedo of water, of clouds, and of the earth on average?
Where does the factor of four come from in balancing absorbed solar radiation with emitted longwave radiation?
Why is Venus so hot at the surface?
How does an actual greenhouse work?

How does the natural atmospheric greenhouse effect work?

How big is the natural greenhouse effect on the earth?
From about what altitude in the atmosphere is IR being emitted at 255 K?
What are the main greenhouse constituents in our present earth atmosphere?

What is the “atmospheric window”?

What gaseous constituents might “smear” this atmospheric window?

What are some possible consequences of anthropogenic global warming?

**8. Heat transport.**

How far are we from the sun?

What is the radius of the earth?

Why are the poles cold and the equator hot?
How does the earth system deal with the fact that more short-wave energy comes into the tropics than long-wave energy is emitted, while the reverse is true of the high latitudes?

What is sensible heat transport?

What is latent heat transport?
About what fraction of solar energy reaching our planet goes into evaporation?

How much energy does it take to evaporate 1 kg of water?

**9. Implications of the distribution of land and sea.**

What are some of the differences between the properties of the land and the ocean?

 What fraction of the earth's surface is covered by ocean?

How can the land/sea differences explain the fact that earth is colder in January when it is closer to the sun?
What is a gyre?

What is the thermocline?

About how deep is it?

About how deep are the oceans?
How does the ocean introduce a long time-scale into climate change issues?
If the sea surface were warmer, would you expect more or less carbon dioxide and water vapor in the air?
How can the temperature of a nearby ocean control whether there is a desert or not?

**10. Monsoons.**

What is a monsoon?
Be able to sketch the relationship among the overturning circulation, warm and cold locations, and surface low and high pressure systems for winter or summer.

**11. Implications of planetary rotation.**

What is the Coriolis effect?

In what direction does wind push the ocean surface layer in the northern hemisphere (Ekman transport)?
On which side of the oceans does warm water move poleward?
Where is upwelling most likely to occur?

Where are deserts most likely to occur?

On which sides of the continents is it usually the rainiest?

**12. Thermohaline circulation.**

What controls the density of sea water?

Where is the ocean the warmest?

Where is it the saltiest?

What physical processes can affect the salinity of water?

About how much salt is in a cubic meter of ocean water?
What is the thermohaline circulation?

Why does water tend to sink to the bottom preferentially in the North Atlantic?

What is the "conveyor belt" idea?

Where is carbon dioxide entering the ocean and what does it do to the ocean?

How could an oscillation in global temperature develop from changes in the extent of the North American ice sheet and in the strength of the thermohaline circulation?

**13. ENSO.**

 What is El Nino?

What is the Southern Oscillation?
What are the main characteristics of the tropical atmosphere and ocean during the cold phase of ENSO?

During the warm phase?
What are some practical reasons for trying to understand and predict ENSO?

**14. NAM.**

What is the Northern Annular Mode / North Atlantic Oscillation?
What is the weather in Europe and Eastern North America like during the weak phase of NAM?

During the strong phase?