AOS 610 Prof. Hitchman
Study Guide Questions for the Second Quiz

1. *Continuity equation for constituents*
Write down the continuity equation for the number density of air
and for the number density of a trace constituent.
What is the mixing ratio?
What is the continuity equation for the mixing ratio of a trace constituent?
Why is it useful to use the continuity equation for mixing ratio?
How do you convert from volume mixing ratio to mass mixing ratio?
Contrast the “dynamical approximation” and the “chemical approximation”.

2. *Rotation*
What terms are introduced into the Navier-Stokes equations by our rotating coordinate system?
What is effective gravity?
What are gravitational potential and centripetal potential?
What term relates a vector seen in the rotating system to a vector seen in a fixed reference frame?
What is the Coriolis parameter?
What does ß signify?
What is angular momentum?
Under what conditions is it conserved following the motion?
What is the Rossby number?
What does it mean if the Rossby number is small?
Write down the formulae for the geostrophic wind.
Be able to estimate them given a pressure gradient or height gradient and the latitude.
What is a synoptic chart?

3. *Thickness and thermal wind*
What are geopotential and geopotential height?
What two equations are combined to obtain the "hypsometric" or thickness equation?
What is the scale height?
Be able to calculate thickness, given a mean temperature between two pressure levels.
In an isothermal atmosphere, what is the formula for pressure variation with altitude?
What is the corresponding formula for density variation with altitude?
Write down the two components of the thermal wind law.
Can you estimate the geostrophic wind at some altitude, given the surface wind, mean layer temperature, temperature gradient, and latitude?
State the thermal wind law for each component using the words “poleward”, “eastward”, and “upward”.

4. *Equation of state*

What is the ideal gas law for the atmosphere?
What is the range of salinity, temperature, and density in the world's oceans?
How does pressure vary in the ocean and in the atmosphere?
Describe two scenarios involving temperature and salinity, one in which water sinks at high latitudes and one in which water sinks at low latitudes.
How can the Atlantic meridional overturning circulation (AMOC) cause climate variations?

5. *Conservation of energy*

Define internal, kinetic, stored, and potential energies per unit volume.
In the equation for stored energy, what are the five processes represented on the r.h.s.?
What is the rate of viscous dissipation per unit volume?
How does viscous dissipation affect kinetic energy and internal energy?
Which work terms only affect kinetic energy?
Which work terms only affect internal energy?
In plane Couette flow, what does the surface work term do?
Write down the temperature equation and provide an interpretation for each term.
What are the three diabatic processes?
What are the approximate percentages of internal, potential, and kinetic energy in the atmosphere?
What is available potential energy?
How is wind produced?
What happens to kinetic energy?

6. *Potential temperature, dry and moist adiabatic lapse rates*

What is an adiabatic process?
Define potential temperature in terms of entropy and in terms of pressure and temperature.
How does heating relate to a change in entropy?
What are some of the benefits of the isentropic perspective?
What are the “overworld”, the “middle world”, and the “underworld”?
Where does the 350 K surface cross from the troposphere into the stratosphere?
Do any isentropic surfaces connect the subtropical ocean surface with the polar tropopause?
Be able to derive the dry adiabatic lapse rate. What is it's value?
What condition determines whether a fluid is statically stable, neutral, or unstable?
What is a buoyancy oscillation?
What is a typical buoyancy period and frequency in the troposphere?
Derive the buoyancy frequency from the Boussinesq approximation and eddy mixing length theory.
How is a hurricane like a heat engine?
What is latent heat of condensation?
What is equivalent potential temperature?
Compare the moist adiabatic lapse rate with the dry adiabatic lapse rate.

Sketch vertical profiles of potential temperature and equivalent potential temperature in the tropics.

7. *Circulation, Vorticity, and Potential Vorticity*

Define circulation around a closed loop.
Show that solid body rotation has a vorticity of twice the angular frequency.
What is planetary vorticity?
What is absolute vorticity?
What is zonal mean absolute vorticity?
What is the recipe for forming a vorticity equation?
State the conservation law for absolute vorticity for large scale flow.
Be able to identify the "stretching term", "tilting/twisting term", and "baroclinic term".
What is shallow water potential vorticity?
What is Ertel's potential vorticity?
Describe the "beta effect".
How does conservation of potential vorticity lead to Rossby waves on a rotating sphere?
How does conservation of potential vorticity lead to Rossby waves in a rotating tank?
What is Rossby wave breaking?
How can PV be used to describe cyclogenesis and anticyclogenesis?
What is a tropopause fold?

8. *Turbulence*

What is a good recipe for mixing?
What are some properties of turbulence?
What is the "enstrophy cascade"?
Give the units for energy dissipation rate per unit mass and the units of kinematic viscosity.
Using dimensional analysis, derive the Kolmogorov microscale, l*.
How big is l*, typically?
If more energy is put into the system at large scale, what will happen to l*?
Define wavenumber.
What are the units of kinetic energy spectrum?
What is "red noise"?
Using dimensional analysis, evaluate the power dependence of the kinetic energy spectrum on energy dissipation rate and wavenumber.
What is the $k^{-5/3}$ power law and what does it represent?
What is the inertial subrange?
What does a k^{-3} power law represent?
Why is it harder for eddies to transfer energy to smaller scales in 2D compared to 3D?

9. *Contrast the following types of waves*

free versus forced

internal versus external
stationary versus travelling
steady versus transient
linear versus nonlinear
dispersive versus nondispersive

10. *Wave definitions*
Define phase for a 3D plane wave.
Be able to determine the sign of m or l from the phase axis orientation.
Define wavenumber, frequency, phase velocity, trace velocity, and group velocity.
What is the difference between the x-component of c_p and c_t?
Be able to describe in words what a dispersion relation is.
Know the main procedures of the linear perturbation method for obtaining a dispersion relation.
How fast do sound waves travel and are they dispersive?

11. *Momentum fluxes*
What is a flux?
What is a flux convergence?
What are Reynolds stresses?
What is an eddy diffusion coefficient?
Use linear mixing length theory to represent vertical flux convergence in the form of diffusion.
How can momentum flux be up-gradient?
Sketch a streamline pattern in (x, y) that transports westerly momentum northward.
Sketch a streamline in (x, z) that transports westerly momentum downward.