Name: ___________________

GEOL/ENVS3520 Spring 2009 Hour Exam #1

Enter your name, the date, your ID number, and a made-up 4-number code (for later identification of your test results) on the separate test sheet.

Carefully read each of the 47 questions below and choose the best answer. Enter your answer besides the corresponding question number on the separate test sheet. 2 pts. each. The last question requires a written answer, worth 6 pts.

This document is double sided, answer questions on both sides.

1) Which of the following gases is most abundant in Earth's atmosphere
   a. oxygen (O_2)
   b. nitrogen (N_2)
   c. argon (Ar)
   d. water vapor (H_2O)
   e. carbon dioxide (CO_2)

2) A positive coupling describes an interaction whereby
   a. something decreases causing something else to decrease
   b. something increases causing something else to increase
   c. something increases causing something else to decrease
   d. both b.) and c.)
   e. both a.) and b.)

3) Positive feedbacks tend to
   a. bring systems toward equilibrium
   b. increase the rate of change in the system
   c. be good for the system
   d. stabilize the system
   e. all of the above

4) An example of a negative feedback in the Earth climate system is
   a. the sea ice – albedo feedback
   b. the temperature - water vapor feedback
   c. the temperature – infrared radiation feedback
   d. all of the above
   e. none of the above

5) Radiation refers to
   a. the transfer of energy from a source through space
   b. the transfer of energy by fluid movement
   c. the transfer of energy by molecular contact
   d. all of the above
   e. none of the above

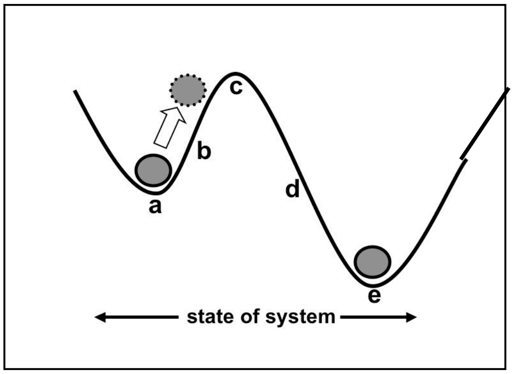

Figure 1. System stability diagram. The ball and topography represent the state of the system. The open arrow represents the size of a hypothetical forcing

6) In the stability diagram in *Figure 1*, which position is most stable with respect to the size of the indicated forcing?

a. position a
b. position b
c. position c
d. position d
e. position e

7) Looking again at the stability diagram in *Figure 1*, which position represents a state of unstable equilibrium at which a small perturbation may lead to continuous change in the state of the system.

a. position a
b. position b
c. position c
d. position d
e. position e

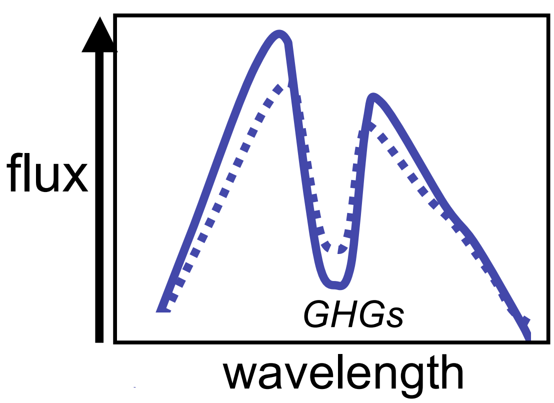

Figure 2. The part of the curves labeled "GHGs" indicates a region of absorption by green house gases.

8) In the spectrum of outgoing earth radiation (as seen from space) above,

a. the dashed curve represents a spectrum for fewer GHGs in the atmosphere
b. the solid curve represents a spectrum for fewer GHGs in the atmosphere
c. the solid curve indicates a higher ground temperature
d. both a. and c.
e. both b. and c.

9) In the next hundred years, will land temperatures change more than ocean temperatures

a. yes, because CO_2 is emitted by people on land
b. yes, because the ocean can store heat without much temperature change
c. no, because ocean water absorbs CO_2
d. no, because both the ocean and land are in radiative equilibrium
e. no, because the greenhouse effect is the same everywhere

10) The present concentration or "mixing ratio" of methane in the atmosphere is about 1700 ppb, meaning

a. 1700 billion molecules of methane for every molecule of air
b. 1700 molecules of methane for every billion molecules of air
c. 1700 molecules of air
d. 1700 molecules of methane
e. 1700

11) Planet "Farser" is now <u>*three*</u> times farther from the Sun than is the Earth. Its received solar radiation is therefore

a. the same as the Earth's
b. three times that of the Earth's
c. one third that of the Earth's
d. one ninth that of the Earth's
e. none of the above

12) A blackbody

a. perfectly absorbs radiation
b. perfectly emits radiation
c. perfectly reflects radiation
d. all of the above
e. both a.) and b.)

13) Under the influence of a constant (unchanging) input of energy a blackbody will heat up until

a. it radiates as much energy as it receives
b. it radiates less energy than it receives
c. it reaches a radiative equilibrium temperature
d. both b.) and c.)
e. both a.) and c.)

14) The Sun's emitted radiation spectrum peaks near the region of

a. visible light
b. infrared radiation
c. microwave radiation
d. the equator
e. radio-wave radiation

15) Earth's surface temperature is warmer than its calculated radiative equilibrium temperature because

a. Earth's true albedo is much smaller than ~0.3
b. the solar radiation at the top of the atmosphere is actually much greater than ~1365 W/m^2
c. the Stefan-Boltzmann constant is not well established
d. the atmosphere traps infrared radiation that is being emitted from Earth back toward space
e. the Earth is not at thermal or radiative equilibrium

16) Earth's radiation temperature is about ~15 °C and that of the Sun is ~5800 °C, thus

a. the flux of Earth's emitted radiation is much larger than the Sun's
b. the flux of the Sun's emitted radiation is much larger than the Earth's
c. the Sun's emissions peak at longer wavelengths than the Earth's
d. the Sun's emissions peak at shorter wavelengths than the Earth's
e. both b. and d.

17) Earth's planetary albedo of ~0.3 is dominated by

a. ice
b. vegetation on land
c. high latitude oceans
d. clouds and low latitude oceans
e. asphalt

18) If Earth's actual planetary albedo were 0.1 instead of ~0.3

a. Earth's surface temperature would be higher
b. Earth's surface temperature would be lower
c. Earth's surface temperature would be unchanged
d. the flux of outgoing infrared radiation would increase
e. both a.) and d.)

19) Incoming solar radiation at the top of the atmosphere is ~1360 W/m^2 and the Earth's emitted radiation is ~ 240 W/m^2. The large difference is due to the fact that

a. the Earth is not in radiative equilibrium
b. some of the incoming solar radiation is reflected back to space and is thus not absorbed
c. the Earth must be shedding lots of energy by some other mechanism than radiation
d. the Sun's radiation is intersected by Earth as a disc (area πr^2), but the Earth absorbs and emits radiation as a continuously rotating sphere (area $4\pi r^2$)
e. both b.) and d.)

20) The most abundant greenhouse gas is

a. ozone (O_3)
b. water vapor (H_2O)
c. carbon dioxide (CO_2)
d. nitrous oxide (N_2O)
e. Freon 11 (CFC-11)

21) Careful measurements of the globally well-mixed greenhouse gases CO_2, CH_4 and N_2O trapped in air bubbles in Antarctic ice cores tell us that

a. the concentrations of these gases began to rise ~100 years ago
b. the concentrations of these gases began to fall ~100 years ago
c. the concentrations of these gases has not changed in the last 100 years
d. only one of these gases began to rise ~100 years ago
e. none of the above

22) Greenhouse gases selectively absorb radiation at certain wavelengths

a. by sensible heating
b. by excitation of molecular rotation, bending and stretching motions
c. by conduction
d. as a black body
e. all of the above

23) Which of the following greenhouse gases have recently begun to decline in atmospheric concentration?

a. methane (CH_4)
b. water vapor (H_2O)
c. carbon dioxide (CO_2)
d. nitrous oxide (N_2O)
e. Freon 11 (CFC-11)

24) Some greenhouse gases are more effective on a molecule per molecule basis than others because

a. they selectively absorb short wave radiation
b. their absorption spectra overlaps those of water, carbon dioxide and methane
c. they both absorb and emit radiation
d. they absorb long wave radiation in the window of peak transmission to space
e. they are anthropogenic

25) Why is the density of lower atmosphere greater than that of the upper atmosphere?

a. because the lower atmosphere is warmer
b. because the chemical composition of the lower atmosphere is different
c. because Earth's gravity tends to pull air molecules toward the bottom of the atmosphere
d. it isn't, like water, air is not compressible
e. none of the above

26) The troposphere

a. is generally marked by a minimum of temperature near the top
b. is generally marked by a maximum of temperature near the bottom
c. is heated from the bottom
d. is the lowest layer of the atmosphere
e. all of the above

27) The vertical temperature (T) profile for dry and moist air differ in the following way(s) and for the following reason(s):

a. T falls more rapidly with height in the moist case
b. T falls less rapidly with height in the moist case
c. the condensation of moisture effectively adds heat to the profile as height increases
d. both b. and c.
e. one can’t tell without a complex model

28) The stratosphere is warmer near the top than at the bottom

a. because it is upside down
b. because of absorption of radiation and heating by water vapor
c. because of absorption of radiation and heating by ozone
d. because of its unusually high density
e. none of the above

29) The amount of water vapor that air can hold

a. depends directly on pressure
b. depends directly on temperature
c. depends directly on altitude
d. depends directly on density
e. none of the above

30) In thinking about the relationship between fossil fuel burning, atmospheric CO_2, temperature and atmospheric water vapor, we may consider

a. CO_2 to be a forcing or perturbation
b. water vapor to be a negative feedback on temperature
c. water vapor to be a positive feedback on temperature
d. both a. and b.
e. both a. and c.

31) The Inter-Tropical Convergence Zone (ITCZ) is

a. always located just over the equator
b. an area of moisture convergence and great precipitation
c. located between the two Hadley cells
d. moves seasonally with the Sun
e. all but a.)

32) Areas of high surface pressure in the extra-tropics (~25-30° latitude) are generally associated with

a. descending moist air
b. rising moist air
c. descending dry air
d. rising dry air
e. none of the above

33) Absorbed radiation exceeds emitted radiation in the tropics while the opposite is the case at higher latitudes and

a. this leads to long term heating of the tropics
b. this leads to long term cooling outside the tropics
c. these local imbalances are compensated by transport of energy from the poles towards the equator
d. these local imbalances are compensated by transport of energy from the equator toward the poles.
e. these local imbalances are compensated by transport of energy in the direction of Earth's rotation

34) Within the hydrologic cycle, there is

a. an excess of precipitation over land
b. an excess of precipitation over the oceans
c. a net transfer of water vapor from the oceans to land
d. a net transfer of runoff from the land to the oceans
e. all but b.)

35) In a warming world, changes in evaporation and latent heating

a. are likely to amplify the hydrologic cycle
b. are likely to weaken the hydrologic cycle
c. are unlikely to influence the hydrologic cycle
d. only matter over the oceans
e. none of the above

36) Conditions that favor the development of hurricanes include

a. warm surface waters
b. pronounced vertical wind shear
c. gentle steering winds
d. sensible and latent heating
e. all but b.)

37) The circulation of the *upper* ocean is largely

a. driven by density contrasts
b. driven by wind stress
c. restricted primarily to the upper few hundred meters
d. both a.) and c.)
e. both b.) and c.)

38) Ekman transport in the upper ocean

a. is 90 ° away from the wind direction
b. results from wind stress
c. results from friction between moving water layers
d. results from the Coriolis effect
e. all of the above

39) Geostrophic ocean current flows are
  a. due only to the Coriolis effect
  b. due only to the pressure gradient force exerted by a pile of water
  c. due to upwelling
  d. due to downwelling
  e. balanced flows related to both Coriolis and pressure gradient forces

40) Upwelling occurs most commonly
  a. in association with *divergence* along the equator
  b. in association with *divergence* along eastern margins of the ocean basins
  c. in association with *convergence* along western margins of the ocean basins
  d. both a. and b.
  e. both a. and c.

41) At temperatures close to freezing, _________ exerts the greater influence on sea water density
  a. salinity
  b. temperature
  c. absorbed solar radiation
  d. latitude
  e. albedo

42) ^{14}C, the radioactive form of carbon, is created in the atmosphere *and*
  a. added to ocean waters (as $^{14}CO_2$) when they are at the surface (and in contact with the atmosphere)
  b. progressively lost (due to radio-decay) over time as deep waters remain out of contact with the atmosphere
  c. acts as a kind of radio-decay clock
  d. all of the above
  e. none of the above

43) The transformation of warm salty surface water in the N. Atlantic to cold salty deep water (i.e., deep water formation) is associated with
  a. heat release from the ocean to the atmosphere above
  b. heat release from the atmosphere to the ocean beneath
  c. the poleward transport of heat at the ocean surface by the conveyor
  d. none of the above
  e. both a. and c.

44) Future warming might be expected to lead to
  a. increased ice melt around the N. Atlantic
  b. reduced salinity of the N. Atlantic
  c. a weakening of deep water formation in the N. Atlantic
  d. any or all of the above
  e. none of the above

45) A key uncertainty in our ability to forecast the climate response to increased greenhouse gas concentrations is
a. the heat capacity of ocean water vs. the land surface
b. the relationship between the saturation vapor pressure of water and temperature
c. the potential mix of “albedo” (cooling) vs. “greenhouse” (heating) clouds
d. the relationship between temperature and radiation
e. the interaction of long wave radiation (Earth light) with CO_2

46) El Nino (and the so-called Southern Oscillation) is a complex interaction between the ocean and atmosphere that includes
a. changes in upwelling regime in the E. Pacific
b. changes in the location of convection and rainfall
c. changes in the easterly trade winds
d. changes in the Walker Circulation (i.e., the E-W overturning cells in the tropics)
e. all of the above

47) In the future, climate change *in the tropics* is likely to influence
a. primarily annual average air temperature
b. precipitation patterns and amounts
c. monsoon intensity and variability
d. none of the above
e. both b.) and c.)

48) (6 pts.) On very long timescales (millions of years) CO_2 is released to the atmosphere by volcanoes and removed from the atmosphere by the chemical weathering of silicate rocks. The rate of silicate weathering tends to increase when temperatures increase, while temperature itself is influenced by CO_2 via the greenhouse effect.

Consider the system components "atmospheric CO_2", "temperature" and "silicate weathering" and draw a diagram that represents these components and the couplings discussed in the story line above. From this, determine whether the overall feedback is negative or positive, and whether any initial change would be weakened or strengthened by the feedback.

Name ___________________________