1. (26 points) Which of the following statements are true (T) or false (F)?

__T__ Climate scientists believe that, due to human activities, Earth’s present climate may be changing faster now than it has in the past (page 1)

__T__ Global warming and climate change are terms that refer to the same environmental issue, specifically the alteration of Earth’s surface temperature and climate due to release of greenhouse gases to the atmosphere. (page 3-4)

__F__ Greenhouse gases are important because they absorb visible radiation in the earth’s atmosphere. – they absorb infrared radiation (page 2, 47-48)

__F__ Measurements of gases in ice cores indicate that carbon dioxide (CO\textsubscript{2}) abundances in Earth’s atmosphere have not changed over the past 240,000 years. (page 5, figure 1-3, page 12, figure 1-9)

__F__ CO\textsubscript{2} is the only known greenhouse gas in the earth’s atmosphere. (page 5, 47, figure 3-13)

__T__ The idea that Earth’s is a self-regulating system with biota playing an important role is called the ‘Gaia hypothesis’. (page 15)

__F__ The ozone hole is a good example of a change in the atmosphere that is due to natural causes. (page 2, 7-9)

__F__ The term “albedo” refers to the absorption of radiation. (page 24)

__F__ Without an atmosphere, the earth’s temperature would be a frigid –100 °C. (page 42-43, 46)

__T__ Latent heat refers to energy gained or lost when water changes phases. (page46)

__T__ Earth’s average global surface temperature has increased less than 1 °C over the past 150 years. (page 6, figure 1-4)

__T__ Over the past 400,000 years, CO\textsubscript{2} abundances in Earth’s atmosphere have correlated well with Earth’s temperature. (page 12, figure 1-9)

__T__ Several times this semester the instructor has asked students not to talk during class. I guess you had to be there
2. (24 points) Pick the phrase that best completes each of the following sentences.

a) As the temperature of a blackbody object increases, radiation from that object
   (i)  shifts to longer wavelengths and becomes more intense.
   (ii) shifts to shorter wavelengths and becomes more intense. (page 39-40)
   (iii) shifts to shorter wavelengths and becomes less intense.
   (iv) shifts to longer wavelengths and becomes less intense.
   (v) remains constant

b) Based on the inverse square law, an object that is twice as far from the sun as the earth
   (i) receives four times as much solar flux than the earth.
   (ii) receives two times as much solar flux than the earth.
   (iii) receives the same amount of solar flux than the earth.
   (iv) receives one-half as much solar flux than the earth.
   (v) Receives one-fourth as much solar flux than the earth. (page 38)

c) The sun’s emission consists
   (i) Primarily of visible and infrared light, with some ultraviolet. (page 36-37)
   (ii) of visible light only.
   (iii) of ultraviolet light only.
   (iv) primarily of ultraviolet light, with some visible and infrared.
   (v) of infrared light only.

d) There is a radiation deficit in the polar regions (that is, less incoming solar radiation
   than outgoing thermal radiation) because
   (i) they are dark year-round.
   (ii) liquid water contains more latent heat than does ice.
   (iii) ice has a low albedo.
   (iv) circulation of air carries heat poleward from the tropics. (page 58-59, Figure 4-2)
   (v) all of the above.

e) Molecules are called ‘greenhouse gases’ if they
   (i) absorb all forms of radiation.
   (ii) are green in color.
   (iii) reflect light back to space.
   (iv) absorb infrared radiation, but are transparent to visible light. (page 46-48)
   (v) stop convection of air, like the windows in a greenhouse.

f) The earth's temperature has increased by about _____ over the last century.
   (i) 0.1 °C
   (ii) 0.7 °C (page 6, figure 1-4)
   (iii) 7 °C
   (iv) 20 °C
   (v) none of the above. The temperature cannot change because the earth is in radiative balance.
g) The most abundant gas in the earth’s atmosphere is
   (ii) water vapor (H₂O)
   (iii) carbon dioxide (CO₂)
   (iv) nitrogen (N₂) (page 44, Table 3-2)
   (v) oxygen (O₂)
   (vi) ozone (O₃)

h) The energy flux emitted by a blackbody object goes as
   (i) the temperature squared (T²)
   (ii) the temperature raised to the fourth power (T⁴) (page 40-43)
   (iii) one over the radius squared (1/R²)
   (iv) one over the wavelength (1/λ)
   (v) one over the temperature squared (1/T²)
3. (20 points) Pick the best answer for each of the following questions.

I. Which of the following processes would result in negative feedback on Earth’s surface temperature?
   (a) Enhanced melting of snow and ice with increased temperature. (positive, page 52)
   (b) An increase in water vapor in the atmosphere with increased temperature. (positive, page 51-52)
   (c) Enhanced snowfall in the mountains with increasing temperature. (page 24-27 – substitute snowfall for daisies)
   (d) A decrease in highly reflective clouds as the earth warms. (positive – page 50, figure 3-18)
   (e) All of the above.

II. Earth’s effective temperature is determined from the balance of what two factors?
   (a) Absorption of solar radiation and thermal (infrared) emission back to space. (page 41-42, Figure box 3-1)
   (b) Absorption of solar radiation and reflection of thermal emission by clouds,
   (c) Reflection of visible radiation from the sun and reflection of infrared from the sun.
   (d) Emission of visible light by clouds and absorption of infrared radiation by clouds.
   (e) All of the above.

III. What are the two main factors that determine the direction of the surface trade winds?
   (a) Earth’s tilt and gravity
   (b) Hadley circulation and the coriolis effect (page 60-64, figure 4-3, 4-8, 4-11)
   (c) Global warming and ozone depletion.
   (d) See breeze and sea ice margins
   (e) None of the above

IV. Which of the following are involved in the transport of heat in the Earth system?
   (a) Conduction
   (b) Convection
   (c) Latent heat
   (d) Radiation
   (e) All of the above (page 45-46, figure 3-10)

V. Why are the effects of clouds on the climate system difficult to quantify?
   (a) Clouds move around too quickly to monitor.
   (b) Clouds aren’t really made of water.
   (c) Water droplets are heavier than air.
   (d) Depending on their height, clouds can either warm or cool the surface. (page 53)
   (e) They obscure our view of the surface from space.
4. (30 points) – Complete the paragraph by filling the blanks with the appropriate term, using a term only once. Note that not all terms will be used.

Earth’s _1. general circulation_ is driven by the _2. uneven_ distribution of incoming radiation from the sun and that emitted back to space. Because of the curvature of the earth and differences in _3. albedo_, higher latitudes absorb much less solar radiation than do the tropics. This establishes a temperature _4. gradient_ that results in equator-to-pole motion of air that is commonly referred to as _5. Hadley Circulation_. Warm, moist air in the tropics rises because it is _6. less dense_ than surrounding air that is cooler and drier. This effect is called _7. buoyancy_. The region of convergence of surface winds in the tropics, necessary to fill in for the rising air, is called the _8. ITCZ_. Due to Earth’s rotation, air is deflected at right angles to the direction of motion by the _9. Coriolis effect_. In the northern hemisphere, this deflection results in upper level winds that travel from _10. west to east_ in middle latitudes (e.g. 30-60 °N). The balance between the coriolis effect and the _11. pressure force_ is called _12. geostrophy_.

Because heat is transferred downward more rapidly through the _13. ocean_ than through _14. land_, the land surface heats more rapidly during the day and cools more rapidly during the night than does the ocean, resulting in a temperature contrast that produces a pattern of winds called the _15. sea breeze_. Similar contrasts between continents and oceans lead to seasonal variations in temperature and precipitation, an effect that is called _16. continentality_.

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3. albedo (lecture 8)
7. buoyancy (page 56)
16. continentality (page 70-72)
9. Coriolis effect (page 61-63)
east-to-west (this is tropics - Figure 4-11 page 64)
effective temperature (T of a blackbody radiating same E as Earth - page 41)
general circulation (page 58)
geostrophy (page 66, lecture 9)
gradient (page 59)
Hadley circulation (page 60)
Intertropical Convergence Zone (ITCZ) (figure 4-3, 4-7, 4-9, 4-16, page 59)
land (page 69)
left-to-right
less dense (page 56-57)
more dense
north-to-south
ocean (page 69)
precipitation
pressure force (page 66, figure 4-13)
sea breeze (page 69-70, figure 4-17)
surface temperature
west-to-east (page 60-65, figure 4-11)
uneven (page 59)
uniform