Appendix D.1: Example Midterm Questions for Study Purposes

1. Briefly define and explain the following in the context of this course:
    a. Hadley cell

ANSWER: The lowest latitude circulation cell in the three-cell model of the atmospheric general circulation. It extends approximately from the equator to 30 degrees north and south latitude and has upward motion near the equator, then poleward motion aloft, subsiding air at around 30 degrees north and south and then equatorward flow from 30 degrees north and south at the surface. The surface winds correspond to the observed northeasterly and southeasterly trade winds. The northern and southern hemisphere Hadley cells meet near the equator in the "Inter Tropical Convergence Zone" a band of tropical clouds and precipitation resulting from the upward moving air. The subsiding air at 30 degrees north and south results in clearing skies and corresponds with the subtropical deserts around the world.

    b. Q_E

ANSWER: The latent heat flux. It is part of the energy budget and is a convective flux representing the energy involved in phase changes of water in exchanges between the surface and the atmosphere. Positive values mean a latent heat flux from the surface to the atmosphere from the evaporation or sublimation of water at the surface with the atmosphere gaining water vapour; negative values mean a latent heat flux from the atmosphere to the surface resulting from condensation or deposition of water vapour from the atmosphere as liquid or solid water on the surface.

2. Define the concept of an isotherm line.

ANSWER:

An isotherm is a type of contour line also known as a line of "equal value" on a map or spatial image

Specifically, isotherms are lines of equal temperature and represent spatial locations that have the same temperature. Temperatures are higher than this value on one side of the isotherm, and lower than this value on the other side.

3. Revisit your: Lecture notes, assignments, quizzes, readings, & blackboard quizzes to the end of Week 5, and Labs 0&1, 2 & *don't forget to include the Reflection questions*, and Wx Proj skills up to & including Lab 4. Also note Lab 3 provides good review of lecture Energy Budget material but it isn't specifically tested as we've not yet completed your double submission of it.

ANSWER:

See your lab assignments, Appendix A handouts, and posted answer keys.

4. What is a snow pillow?

ANSWER:

From the Wx Prj Precipitation hand-out given during Lab 3.

A snow pillow measures the liquid equivalence of snow depth. It usually consists of 4 level stainless steel panels that are connected to each other and a pressure transducer (a sensor that converts pressure into a voltage). Each panel is filled with an antifreeze solution so that snow that falls on it melts into it. The added weight puts pressure on the panels, sending a reading to the pressure transducer whose voltage is converted into an equivalent liquid value and then an equivalent liquid depth of snow.

[Snow pillows are sometimes used at remote sensing stations so that the signal from the pressure transducer is sent via antenna to a computer that can analyze the data.]

5. Given that the radiation temperature of the Earth is about 254 K and assuming it is a black body:
    a. Calculate the flux density of radiation (Wm^{-2}) emitted.

ANSWER: $L\uparrow = \sigma T^4$ where: T = 254 K

$L\uparrow = (5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4})\ (254 \text{ K})^4$

$L\uparrow = 236 \text{ W m}^{-2}$

    b. Report the value determined in part a. to its correct number of significant figures.

ANSWER: $L\uparrow = 236.\text{ W m}^{-2}$ (3 sig. figs.)

    c. Report the name and symbol used for this quantity.

ANSWER: outgoing longwave radiation with a symbol of $L\uparrow$

6. What are: Planck's Law, Stephan-Boltzmann Law, Wien's Law? How are they related?

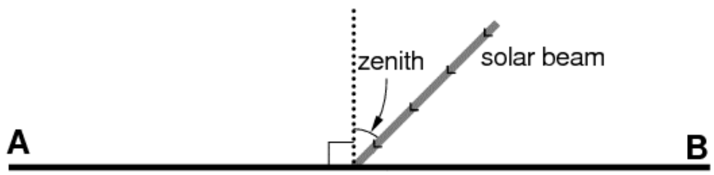
ANSWER:
Planck's Law is the fundamental radiation law that tells us, for a "black body" of a given temperature, the radiation emitted as each wavelength. It results in a curve of Radiation Flux Density per wavelength (y axis) vs wavelength (x axis) for a given temperature.
Stefan-Boltzmann Law, for a "black body" of a given temperature, tells us the the total radiation emitted over all wavelengths ($E = \sigma T^4$, where σ is the Stefan-Boltzmann constant, and T is the temperature of the object in Kelvins).
Wien's Law tells us, for a black body of a given temperature, the wavelength of peak emission ($\lambda_{max} = 2900/T$).
Both Stefan-Boltzmann and Wien's Law come from Planck's Law: S-B is the area under the Planck curve (integration of Planck's Law), and Wiens is the wavelength at the peak of the Planck curve (found as the wavelength where the differential of Planck's Law equals zero).

7. The sun is 20 degrees above the horizon.
    a. What is the zenith angle?
    b. Calculate the flux density of radiation entering the atmosphere.
    c. If the atmosphere attenuates (absorbs and reflects) 20 % of this value and Earth's albedo is 0.25, what is K*, the net short wave radiation?

ANSWERS:

a. Since the Sun is 20 degrees above the horizon, and the zenith angle is defined as the angle between the perpendicular to the horizon and the solar beam, indicating that the zenith angle (Z) must be: $90^0 - 20^0 = 70^0$

← This figure shows the relationships.



b. The flux density entering the atmosphere is determined by:
$I = I_0 \cos Z$ *where*:
I *is the flux density entering the atmosphere*, I_0 *is the solar constant*, Z *is the zenith angle*
$I = I_0 \cos Z = (1361\ W\ m^{-2})(\cos 70^0) = 465\ W\ m^{-2}$

c. To answer this question, use the I value determined above and remove the 20% of attenuated incoming energy to determine K↓ (this is the same as retaining 80%).
Then use Earth's albedo ($\alpha_{Earth} = 0.25$) and K↓ to determine K↑ (K↑= (α_{Earth})(K↓)).
Now compute K* from K*= K↓- K↑.

So the answer is calculated as follows:
$I = 465\ W\ m^{-2}$ but it is attenuated so

K↓ = (0.8)(465 W m^{-2}) = 372.4 W m^{-2}
K↑ = (α_{Earth})(K↓) = (0.25)(372.4 W m^{-2}) = 93.1 W m^{-2}
K* = K↓- K↑ = (372.4 - 93.1) W m^{-2}
K* = 279.3 W m^{-2}

8. During the course we've examined two different Q* relationships:
   a. List the two Q* equations.
   b. What controls Q*? Briefly explain your reasoning.

9. Describe how the Energy Budget ($Q^* = Q_H + Q_E + Q_G$) relates to air temperature changes from daytime to nighttime.

ANSWER:

Q_H, the sensible heat flux, is the heat going into or out of the air that causes its temperature to change. If $Q_H > 0$ then heat is going from the surface to air and T_{air} will increase; if $Q_H < 0$ then heat is going from air to surface and T_{air} will decrease.
During day, Q* (net radiation) is generally positive due to solar radiation; the surplus energy from radiation can go into one or more of $Q_H + Q_E + Q_G$. If $T_{surface} > T_{air}$ then Q_H will be > 0 and T_{air} will increase as sensible heat enters the air.
During night, Q* is generally negative; energy must come from one or more of $Q_H + Q_E + Q_G$ to make up the deficit; if $T_{surface}$ is $< T_{air}$ then Q_H will be < 0 and T_{air} will decrease as sensible heat leaves the air.

10. What is the incoming solar radiation (I) on Feb 14 at 8 a.m. at Prince George, assuming the latitude of Prince George is 54^0N and there is no atmospheric attenuation?

ANSWER:

Use: $I = I_0 \cos Z$ *where:*

I_o = the max solar flux density = $1367\ Wm^{-2}$
I = the incident radiation received by the surface

$\cos Z = \sin\phi \sin\delta + \cos\phi \cos\delta \cos h$

where:

ϕ = the latitude of Prince George = 54^0 N

h = the hour angle (15^0 per hour from solar noon and we assumed that solar noon is the same as local noon). For 8:00 PST → h = (4 *hours* x -15^0/ *hour*) = -60^0

δ = the solar declination (i.e. the latitude where the sun is directly overhead. A positive value indicates ^{0}North; and a negative value indicates ^{0}South). Determine δ using:

$$\delta = -23.4^0 \cos\frac{(360(T_J + 10))}{365}$$

where T_J = the Julian Day = (31+14) = 45 for Feb 14

$$\delta = -23.4^0 \cos\frac{(360(45+10))}{365} = -13.67°$$

or ~14^0 south of the equator

Determine: $\cos Z = \sin\phi \sin\delta + \cos\phi \cos\delta \cos h$

$\cos Z = \sin(54^0 N) \sin(-13.67^0) + \cos(54^0 N) \cos(-13.67^0) \cos(-60^0) = 0.09437$

Substitute $\cos Z$ into $I = I_o \cos Z$:

$I = I_o \cos Z = 1367\ Wm^{-2}\ (0.09437)$

$I = 129\ Wm^{-2}$

11. Write the letter corresponding to the correct answer in the box beside the question for the following multiple choice questions.

[B] 1) Which of the following terms refers to the horizontal transport of any atmospheric property by the wind?
(a) radiation
(b) advection
(c) redistribution
(d) conduction
(e) convection

[C] 2) Which of the following describes how the atmospheric greenhouse effect is mainly produced?
(a) Gases in the atmosphere absorb and re-emit ultraviolet radiation.
(b) Clouds absorb and re-emit visible light.
(c) Gases in the atmosphere absorb and re-emit infrared radiation.
(d) Gases in the atmosphere absorb and re-emit visible light.
(e) Clouds reflect solar radiation back to space.

A

3) At which of the following times of day does the relative humidity usually reach a maximum value?
   (a) the time when the air temperature is lowest
   (b) between midnight and dawn
   (c) the middle of the afternoon
   (d) the time when the air temperature is highest

A

4) Which of the following statements about water vapour is correct?
   (a) Vapour pressure decreases with increasing altitude.
   (b) A decrease in the number of water vapour molecules will increase the vapour pressure.
   (c) If air pressure falls, vapour pressure will increase.
   (d) The vapour pressure is typically higher than the partial pressure exerted by oxygen.

D

5) The surface pressures at the bases of warm and cold columns of air are equal. Which of the following describes the air pressure in the warm column of air compared to the air pressure in the cold column?
   (a) It increases with increasing height more slowly than in the cold column.
   (b) It increases with increasing height more rapidly than in the cold column.
   (c) It decreases with increasing height more rapidly than in the cold column.
   (d) It decreases with increasing height more slowly than in the cold column.

Note: This message and the highlighting will not appear on the test equation sheet; it is provided for studying purposes only. *The yellow highlighted formulas indicate they are definitions, and consequently the values in these formulas are considered to be exact. This should be understood when considering significant figures as these numbers do not limit your rounding of final results.*

Midterm Constants and Formulas

Not all are constants & formulas are used. Additional information can be provided in questions as needed.

$K = °C + 273.15$

$E = \sigma T^4$ and $E = \varepsilon \sigma T^4$

$a_\lambda + r_\lambda + t_\lambda = 1$

$a_\lambda = \varepsilon_\lambda$

$Q^* = K\downarrow - K\uparrow + L\downarrow - L\uparrow$

$\delta = -23.4 \cos\left(\frac{360(T_J + 10)}{365}\right)$

$^0C = \frac{5(^0F - 32)}{9}$

$\lambda_{max} = \frac{2900}{T}$

$^0F = \left[\left(\frac{9}{5}\right)(^0C)\right] + 32$

$\alpha = \frac{K\uparrow}{K\downarrow}$

$\sigma = 5.67 \times 10^{-8}$ W m^{-2} K^{-4}

Solar constant: 1361 W m^{-2}

$Q_E = L_v E_t$

$\beta = \frac{Q_H}{Q_E}$

$I = I_o \cos Z$

$Q^* = K^* + L^*$

$\cos Z = \sin \phi \sin \delta + \cos \phi \cos \delta \cos h$

$P = E_t + r + \Delta S$

Note the decimal in 1000. & understand it's significance when determining significant figures.

$Q^* = Q_H + Q_E + Q_G$

ρ_{water} = 1000. kg m^{-3}

E of 1 mm h^{-1} is equivalent to Q_E of 680 W m^{-2}

$L_V = 2.450 \times 10^6$ J kg^{-1}

Surface Area$_{(sphere)}$ = $4 \pi r^2$

Surface Area$_{(circle)}$ = πr^2

Mean distance between Earth and Sun: $r = 1.500 \times 10^{11}$ m

Radius of the sun: 7.00×10^8 m

Distance from Earth to the moon: 3.84×10^8 m

Radius of the earth: 6.37×10^6 m

Distance from Mercury to the sun: 5.790×10^{10} m