Principles of Energy Balance in Environmental Systems

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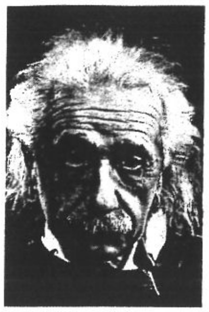
Lecture 2

1. Key for homework: units conversion Calories v. calories
2. Calculating the efficiency of photosynthesis
3. Calculating absorbed shortwave radiation – importance of albedo
4. The three components of shortwave radiation
5. Definitions of shortwave and longwave radiation
6. The Stefan-Boltzman Law for longwave radiation



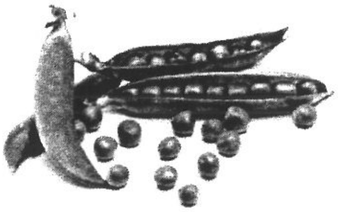
Environmental Plant Physiology 5270 / 6270
Modeling assignment number one

$E = mc^2$

5 points – show your work below

Make strict use of SI units

Name KEY



1. Based on Einstein's famous equation, calculate how much energy is in a typical pea seed. If you could convert all of the dry mass in this pea seed to energy, how many years could you live after eating it?

DIMENSIONAL ANALYSIS

$E = m \cdot c^2$

$= Kg \cdot (m\ s^{-1})^2$

$= Kg \cdot m^2\ s^{-2}$

$E = \frac{Kg \cdot m}{s^2} \cdot m$

Joule = Newton · m

INSERT VALUES

$E = 0.25 \times 10^{-3} * (3 \cdot 10^8)^2$

$= 0.25 \cdot 10^{-3} \cdot 9 \cdot 10^{16}$

$E = 2.25 \cdot 10^{13}$ Joules = 22.5 Terajoules

AVERAGE METABOLIC ENERGY PER DAY

$\frac{2400 \text{ kcalorie}}{\text{day}} * \frac{4.18 \text{ kJ}}{\text{kcal}} = \frac{10 \text{ MJ}}{\text{day}} = \frac{10^7 \text{ J}}{\text{d}}$

$\frac{\text{ENERGY IN PEA}}{\text{ENERGY per day}} = \frac{2.25 \cdot 10^{13} \text{ J}}{10^7 \text{ J/d}} = 2.25 \times 10^6$ days

= 2.25 MILLION DAYS / 365 d

= 6,000 YEARS!

= 6 kiloYEARS

* THERE IS A GOOD CHANCE YOU WILL DIE OF SOMETHING ELSE BEFORE YOU RUN OUT OF ENERGY.

A comparison of the Educational Systems in the United States and China

There are many differences between the American educational system and systems in other countries. I was shocked when I first arrived in this land to know that the American system of education offers students so many possibilities. I was puzzled when I learned that American students are encouraged to understand theories and definitions with their own languages instead of what they exactly memorize from books. More than three years have gone since I attended USU, I am still impressed with these shocks although I have tried to adapt myself to American circumstance of education.

These shocks have driven me to watch the differences in educational systems between the United States and China, and stimulated me to think of the social, cultural, psychological and economic reasons that result in the differences. Many researches in this subject have been made by education administrators and experts. In this short essay, I want to point out some differences in the following three aspects from a foreign student's viewpoint: (1) opportunities of education, (2) priority of education, and (3) student's studying method.

(1) Opportunities of education. One of the major differences in educational systems between the United States and China is that education in the United States is intended for everyone: Chinese schools are basically open to a privileged few intelligent students.

American schools are expected to meet the needs of every child regardless of his ability and also of society itself. This means that not only every child can enjoy the opportunity of education, but also he or she can choose among a great variety of subjects depending on his or her interests, future plans, and level of ability. There are, however, certain basic courses that everyone is required to study.

There is, however, a very different picture in China. Although all children throughout the whole country are required by law to attend school from ages 7 to 16, the emphasis of school is focused on a few very smart students. Most students lose their possibilities of development. It would not be difficult to understand what causes this extreme situation if you know that the proportion of students entering schools of a higher grade is an only criterion to judge a school, and that only 6 percent of the students graduated from high schools can be accepted to universities and colleges. It is this difference that causes different understandings of the priority of education in the two countries.

(2) Priority of education. In American schools, there is less importance given to the learning of facts than is usual in the school system of China. Instead, Americans try to teach their children to think for themselves, to ask questions, to explore, and to develop their own creative abilities. The educational system is based on the idea that if a child is taught to "reason" well and to "research" well, he or she will be able to discover whatever facts he or she needs throughout the rest of his or her life.

Contrary to this idea, Chinese educators and teachers extremely emphasize the importance of imbuing students with facts and accepted knowledge so that while Chinese students study and memorize the facts and knowledge they ignored to develop their own creative abilities. At the same time, this priority of education also brings about another striking difference in students' studying method between the two countries.

(3) Studying method. Chinese students' studying methods are much different from American students. Under the China's educational circumstances, Chinese students are encouraged, although not required clearly, to memorize definitions, basic data, and theories from a designated book. This is based on the realization that all these are admitted basic concepts and knowledge, should be firmly kept in mind in order to do further studies or researches. Influenced by this method, many Chinese students have outstanding grasps of basic courses in a given field, but they are often inactive in participating class discussion, and their imaginations are confined to some extent. In exams, they like to use what they memorize from a book to answer questions because it is seen as excellent if a student can exactly remember a definition or a theory from a book to answer a question in a closing exam. That is the tradition of Chinese education, which can be traced back to more than two thousand years ago.

Even some Chinese students who have been studying in the United States for several years are still accustomed to employ this method although they recognized its problem. This is because, on the one hand, it is not easy for these students to get rid of the tradition that bases on their culture, on the other hand, their language ability is still a barrier for them to accept a new thinking a new method. Nevertheless, it is undoubted that most Chinese students are striving to adapt themselves to the new circumstance of the education of America.

With the increase of the educational exchange between the United States and China, the differences in the two educational systems have been widely recognized. If the two countries can learn from other's advantages to offset its weaknesses, they would enjoy a better educational system respectively.

AN EXAMPLE OF HOW TO CALCULATE THE EFFICIENCY OF PHOTOSYNTHESIS

1. **DEFINE:**

$$\text{EFFICIENCY} = \frac{\text{OUTPUT}}{\text{INPUT}}$$

2. **FIND EQUATION AND INPUT ENERGY**

(1000 Watts m^{-2}) INPUT ENERGY

$$CO_2 + H_2O \rightarrow CH_2O + O_2$$

$$1000 \frac{W}{m^2} * \frac{1\ J}{s \cdot W} = 1000 \frac{J}{m^2\ s}$$

3. **CALCULATE THE ENERGY IN THE OUTPUT**

ASSUME A REACTION RATE OF 30 μmol $m^{-2}\ s^{-1}$ (PHOTOSYNTHETIC RATE)

CH_2O HAS AN ENERGY CONTENT OF 480 KJ per mol so:

$$\frac{30 * 10^{-6}\ mol}{m^2\ s} * \frac{480 * 10^3\ J}{mol} = 14.4 \frac{J}{m^2\ s}$$

4. **CALCULATE EFFICIENCY**

$$\frac{\text{OUTPUT}}{\text{INPUT}} = \frac{14.4\ J\ m^{-2} s^{-1}}{1000\ J\ m^{-2} s^{-1}} =$$

IN FULL SUNLIGHT THE EFFICIENCY OF A SINGLE LEAF CAN BE → **1.44 %**

----- Typical values -----

Reflectance of Shortwave radiation (albedo) (280 to 2800 nm)

Emittance or absorbance of long wave radiation (4,000 to 100,000 nm)

Surface	albedo	emissivity or absorptivity
Theoretically perfect black body	0.00	1.00
Fresh, clean snow	~ 0.9	~ 0.8
Old snow	~ 0.8	~ 0.8 – 0.9
White paper	~ 0.8	~ 0.9
Black paper	~ 0.05	~ 0.9
Moist soil	~ 0.1	~ 0.9
Dry soil	~ 0.2	~ 0.9
Single flat leaf	~ 0.25	~ 0.96
Plant community with vertical leaves	~ 0.23	~ 0.98
Plant community with more horizontal leaves	~ 0.25	~ 0.96
Aluminum foil	~ 0.9	~ 0.03
Human skin	~ 0.5	~ 0.98

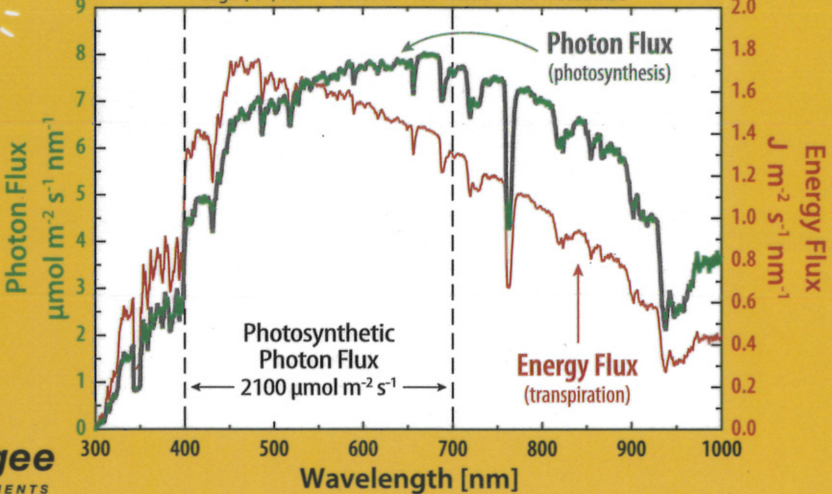
Radiation is either reflected, transmitted, or absorbed by leaves

The fraction of radiation absorbed varies widely depending on the type of radiation.

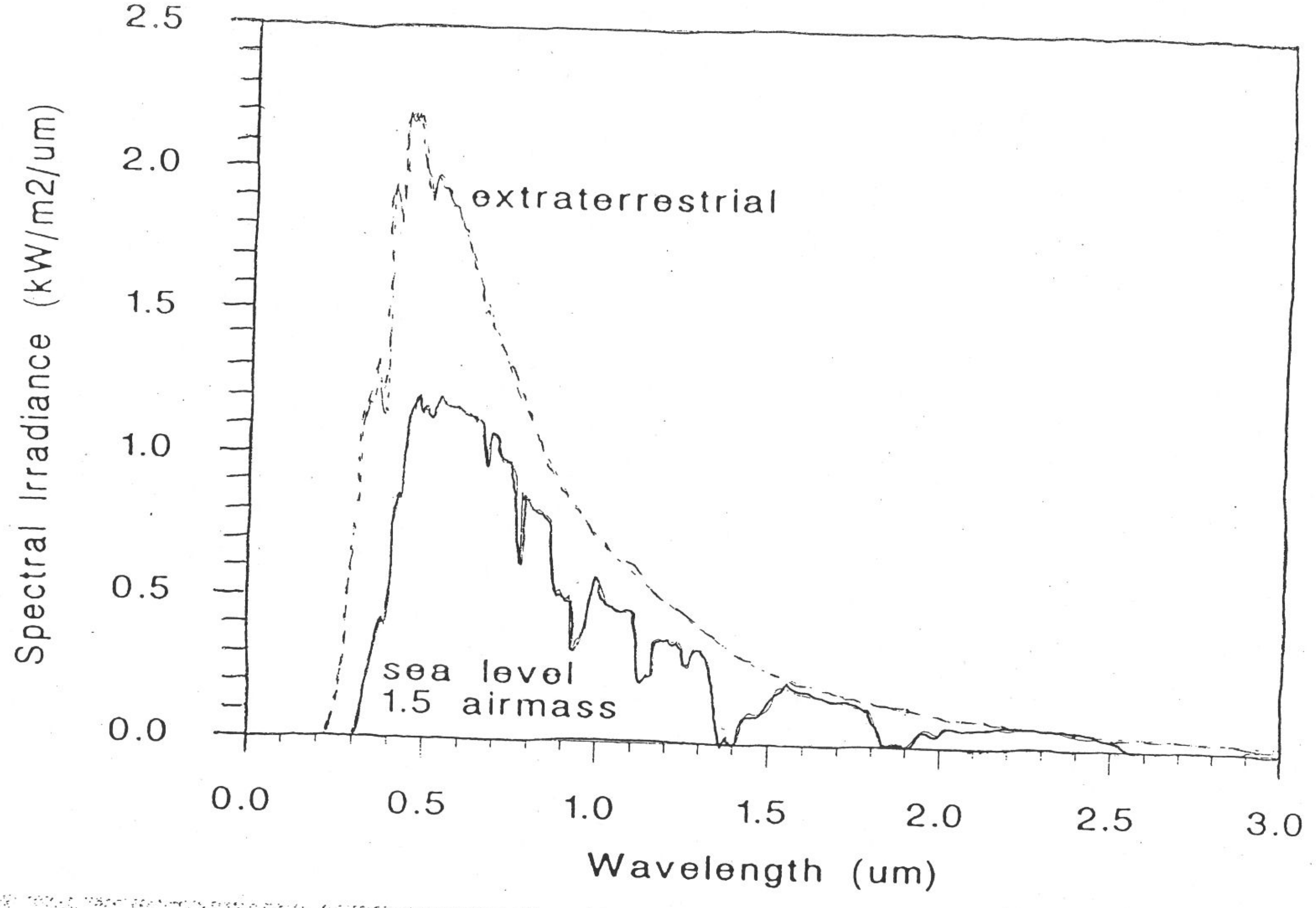
	------ Total shortwave radiation --------		--Total longwave radiation--
	Photosynthetic (400 to 700 nm)	Near infrared 700 to 2800 nm)	Longwave (far infrared) (4,000 to 100,000 um)
Reflection	5 %	45%	4%
Absorption	90 %	10%	96 %
Transmission	5 %	45 %	0 %
Total	100 %	100 %	100 %

Sun Spectrum at Solar Noon on the Summer Solstice

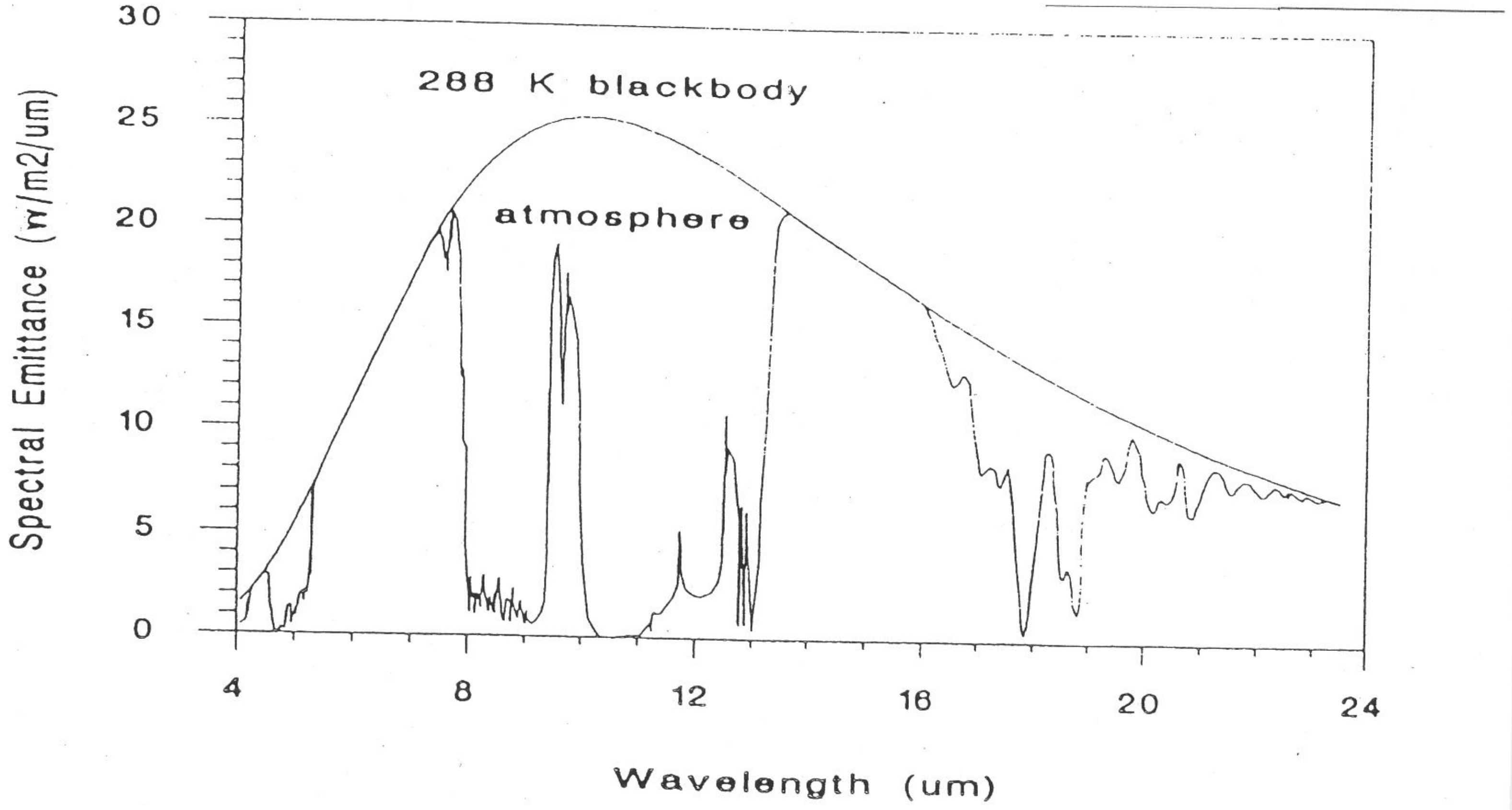
Logan, UT, USA · Elevation 1450 meters · 41.7° N. Latitude



apogee INSTRUMENTS



Spectral Irradiance (kW/m2/um)
2.5
2.0
1.5
1.0
0.5
0.0
extraterrestrial
sea level
1.5 airmass
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Wavelength (um)



Spectral Emittance (W/m2/um)
30
25
20
15
10
5
0
288 K blackbody
atmosphere
4
8
12
16
20
24
Wavelength (um)

Black Body Radiation

associated with temperatures from -40 to +80 ˚C

calculated from the Stefan-Boltzman Law: $E = \sigma * T_K^4$

Stefan-Boltzman Constant (σ) = $5.67 * 10^{-8}$

(add 273.15 to ˚C to obtain temperature in Kelvin)

Surface Temp (˚C)	Emitted Radiation (Watts per m²)	Surface Temp (˚C)	Emitted Radiation (Watts per m²)	Surface Temp (˚C)	Emitted Radiation (Watts per m²)	Surface Temp (˚C)	Emitted Radiation (Watts per m²)
-40	168	-10	272	20	419	50	618
-39	170	-9	276	21	424	51	626
-38	173	-8	280	22	430	52	634
-37	176	-7	285	23	436	53	642
-36	179	-6	289	24	442	54	649
-35	182	-5	293	25	448	55	657
-34	185	-4	298	26	454	56	666
-33	189	-3	302	27	460	57	674
-32	192	-2	306	28	466	58	682
-31	195	-1	311	29	473	59	690
-30	198	0	316	30	479	60	698
-29	201	1	320	31	485	61	707
-28	205	2	325	32	492	62	715
-27	208	3	330	33	498	63	724
-26	212	4	335	34	505	64	733
-25	215	5	339	35	511	65	741
-24	218	6	344	36	518	66	750
-23	222	7	349	37	525	67	759
-22	226	8	354	38	531	68	768
-21	229	9	359	39	538	69	777
-20	233	10	364	40	545	70	786
-19	237	11	370	41	552	71	795
-18	240	12	375	42	559	72	805
-17	244	13	380	43	566	73	814
-16	248	14	385	44	574	74	823
-15	252	15	391	45	581	75	833
-14	256	16	396	46	588	76	843
-13	260	17	402	47	596	77	852
-12	264	18	407	48	603	78	862
-11	268	19	413	49	611	79	872
-10	272	20	419	50	618	80	882