SOLUTION

EXAMINATION IN : MNFFY 221/SIF 4082 Energy and Environmental Physics

Monday 3. December 2001

Problem 1
a) Radiative forcing

The energy balance at the top of the atmosphere requires a constant flux
Flux out – flux in = -ΔI

Assume a doubling of the equivalent CO_2 atmosphere, causes an effective reduction of the earth's long wavelength radiation, magnitude ΔI. To compensate for this change in ΔI, the earth temperature increase. Radiative forcing (given in W/m^2) describe the direct effect of a change in the concentration of a specific gas or atmospheric component.

b)
A certain change in temperature will cause a lot of effects reinforcing it. A few counteracting – thus feedback mechanisms. Some examples for the climate research

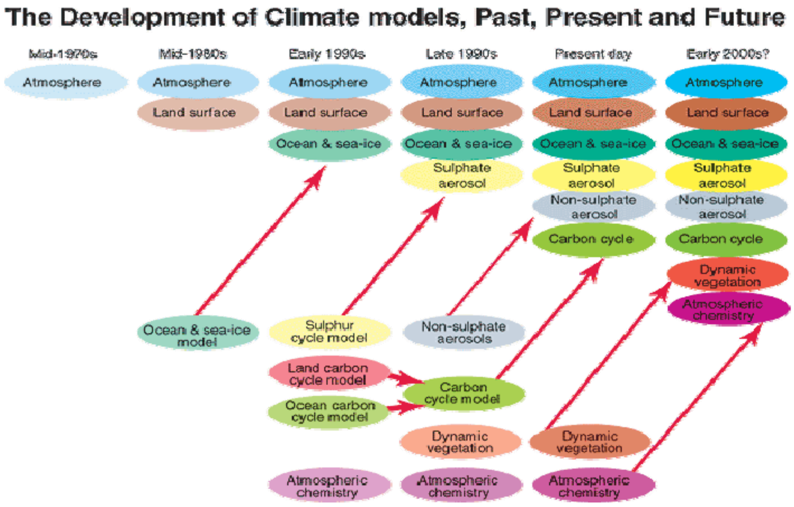
1) Melting of ice – snow, reduced surface albedo
2) Increased water vapour – smaller transmission t_a – higher backscatter
3) Same for increased cloud cover

4) a) higher sea temp gives less CO_2 in ocean – higher air concentration. b) high polar temp causes decreased ocean circulation cecreased CO_2 absoprtion c) faster decay of organic material gives more CO_2 and CH_4

5) Increased CO_2 increased growth reduced albedo.

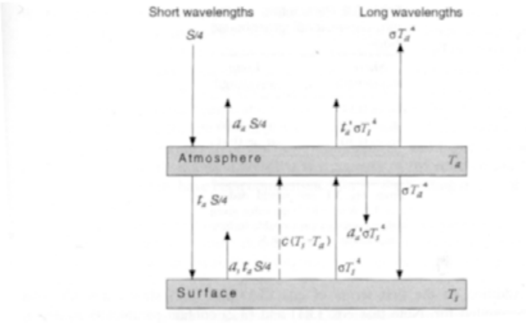
c)

atmosphere, land surface, ocean-sea ice, sulphate aerosol, non sulphate aerosols, carbon cycle, dynamic vegetation, atmospheric chemistry.



Problem 2

a) Fig. 3.2 in textbook (B&G) p. 31



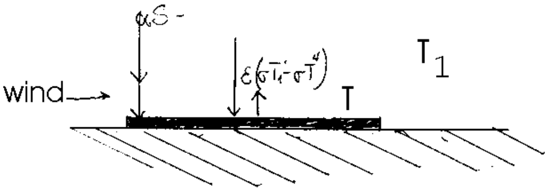
Short wavelength radiation, Long wavelength radiation, Convection

b)

Figure: describes some of the fluxes . Conduction between plate and earth is not marked on the figure.

T: surface temperature

T_1: ambient temperature



$\alpha S + \varepsilon (\sigma T_1^4 - \sigma T^4) + h_c (T_1 – T) + q_t = 0$

α: Absorption coefficient for the surface, = 1 for a black surface

S: Short wave solar irradiance

ε: emission coefficient for thermal radiation

σ: Boltzmans constant

h_c heat transfer number for convection depending on wind speed, for instance $h_c = 23$ when wind speed = 5 m/s

q_t: transient heat current, conduction. (relevant for bottom side of the plate)

c)

examples p. 376 in T&W)

$$E_o = \int_{z=z_1}^{z_2} \rho_r A c_r G(z-z_1)dz = \rho_r A c_r G(z_2 - z_1)^2/2$$

ρ_r: rock density,

A: Cross section to be studied

c_r: Specific heat capacity

G: temperatur gradient dt/dz

z depth

E_0 useful heat content

ex. At 7 km the temperature 40x7=280 K above the surface.

At 140/40 = 3.5 km there is no useful heat.

$E_0 = 2700$ [kg/m^3] 1 km^2 820 [J/kg K] $(3.5)^2$ [km^2] 40/2 [K/km] = 5.42 10^{17} J/km^2

Problem 3

Typical structure for a solar cell:

Fig. 7.1 from T`&W

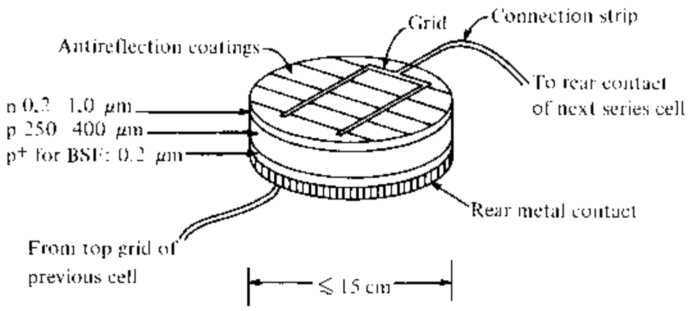


Fig. 7.1 **Typical structure of n–p junction solar cell. The cover (glass or plastic) above the cell, and the filler between the cover and the cell, are not shown. BSF: back surface field**

p-n junction

p and n type material (p becomes slightly negative, n positive), Voltage V_B across the junction. ($V_B \approx 0.6$V)

Junction currents: Generation I_g Recombination I_R (drift) ,

Biasing the material forward biasing cause a current to be run.

Forward bias $I_g << I_R$, Reverse bias: $I_R = 0$

Current I is proportional with the forward biased voltage V., $I = I_0$ for reverse biased cell. I_0 depends on temperature.

Power generation from a solar cell corresponds to conditions of diode forward bias. Potential difference across the semiconductor cell V_B is due to both forward biasing and band displacement. Will vary with the external current I. Absorption of active photons ($h\nu \quad E_g$) to create a further current with power generating capability. The equivalent circuit for a solar cell.

Fig 7.14 from T&W.

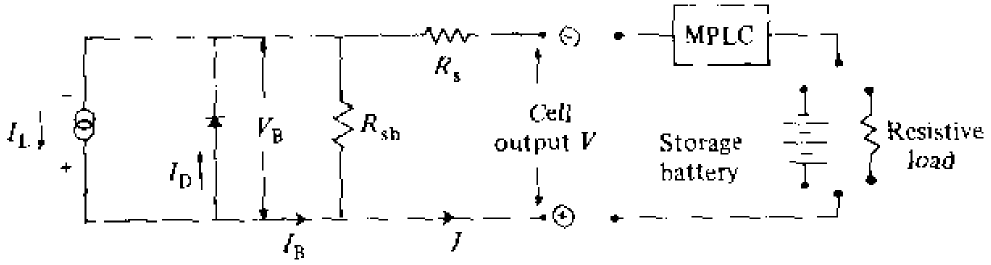


Fig. 7.14 Equivalent circuit of a solar cell. Also drawn are examples of loads *with* maximum power load control (MPLC) to *insure peak power operation*

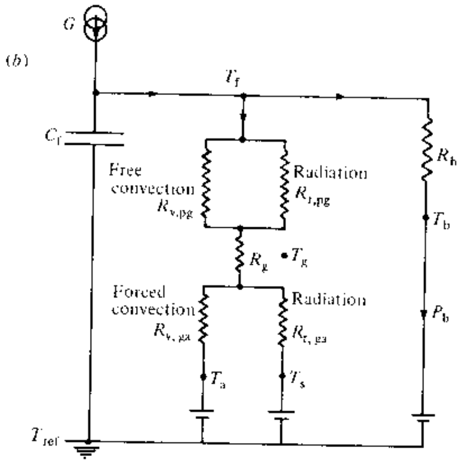
Limiting cell efficiency.

1. Top surface contact obstruction (loss 3%)
2. Reflection at the top surface (loss 1%)
3. Photon energy less than band gap (loss 23%)
4. Excess photon energy (loss 33%)
5. Quantum efficiency (loss 0.4%)
6. Collection efficiency
7. Voltage factor (loss 22%)
8. Curve factor (loss 4%)
9. Additional curve factor A (loss 5%)
10. Series, shunt resistance,

Total efficiency: Delivered power (for Si 10-14%)

b)

Figure 5.4 (T&W)



$R_{tot} = \{1/R_b + 1/R_{pa}\}^{-1}$

$R_{pa} = \{1/R_{v,pg} + 1/R_{r,\,pg}\}^{-1} + R_g + \{1/R_{v,ga} + 1/R_{r,\,ga}\}^{-1}$

c)

Selective surfaces can be a metal-semiconductor stack.

High absorption and emission in short wavelength range ($\lambda<3$ μm), low for thermal radiation ($\lambda>3$ μm) .

Semiconductors are more ideal and metal. By combining both an optimum can be reached. Good conduction from the material into the metal.

Problem 4

a)

Dominant process

$^{235}U + n(\text{slow}) \rightarrow {}^{236}U \rightarrow X + Y + \nu n \text{ (fast)}$

$\nu \approx 2.34$, fast neutrons have energy on average 2 MeV, Slow neutrons are thermal T = 293 K, Fission products can vary.

A parentheses: In real life ^{238}U will also absorb neutrons, leading to ^{239}U and ^{239}Np to ^{239}Pu. ^{239}Pu is fissinable itself. At the end of the fission process it produces 50% of the fissions. ^{239}Pu has different properties than ^{235}U. Reactors has to be design according to their planed lifetime.

THese fast neutrons has to be slowed down by a moderator material. More efficient as the mass of the moderator material reduces, thus H_2O and D_2O is mostly used.

Description of main components in the reactor.

Fig. 4.38 (B&G)

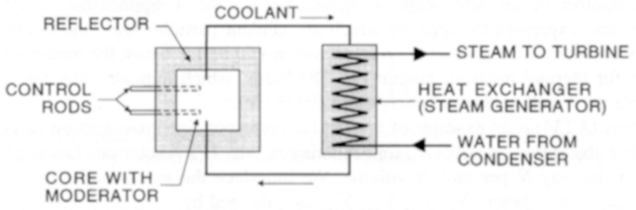


Figure 4.38 Scheme of a nuclear reactor system. The heat from the reactor core is taken away by a coolant. A reflector tries to keep as many neutrons in the core as possible, whereas control rods can absorb superfluous neutrons if necessary

b)

η: fission yield; number of fast neutrons per slow neutron absorbed, $\eta < \nu$. (for instance $\eta=1.33$)

$\eta=\nu\{[N(235)\sigma_f(235)]/[N(235)\{\sigma_f(235) + \sigma_c(235)\} + N(238)\,\sigma_c(238)]\}$

σ_f cross section for slow neutron to be absorbed without fission

σ_f cross section for slow neutron to be absorbed with fission

ε: the fast fission factor . Number of fast neutrons inducing a new fission in ^{238}U and ^{235}U or ε, ε is slightly higher than 1.

p: resonance escape probability. Probability of fast neutrons not to be absorbed by ^{238}U as it is slowed down by the moderator due to resonance phenomena in moderator material. p increase with less moderator matieral

f: thermal utilization factor. Slow neutrons absorbed by the moderator material or cladding of fuel elements. f increase with more moderator material.

The product pf has a maximum at a certain ratio between moderator material and fuel.

Number of fast neutrons will be: $\eta\varepsilon pn$. n number of slow neutrons

A fraction of fast neutrons l_f will leak out of the reactor, leaving $(1- l_f)$ and similar a fraction l_s of slow neutron can leak out of the reactor $(1- l_s)$, but due to the size of the reactors this effect can usually be ignored.

The total number of available slow neutrons ready for a new round of fission will be

$nk = \eta\varepsilon pfn$, k is called multiplication factor.

$k = \eta\varepsilon pf$

The magnitude of k depends on the ratio of moderator material and fuel are approximately 1 (between 0.9 and 1.1)

c)

Bq: number of nucleus decaying per second [s^{-1}]

Gy: Energy absorbed per kg [J/kg]

Sv: 1 Gy $\bullet$ Q = 1 SV [biological weighted J/kg]

Q: quality factor dependent on type of radiation,
Q=1 for X-rays, γ-rays, electrons and muons
Q=5 for neutrons with energies < 10 keV, > 20 MeV and protons with energy > 2 MeV
Q=10 for neutrons with energies from 10 keV to 100 keV and 2 MeV to 20 MeV
Q=20 for other neutrons and α-particles and other particles with a charge larger than one

Radon is the largest health risk in Western world.