PHY392 Midterm Solutions 2010

1) Radiation in the atmospheric window ($800-1000\ cm^{-1}$) corresponds to emission

a) from the surface.

From the figure, the brightness temperature is:

3 Panel (a) : 320 K

Panel (b) : 280 K

Panel (c) : 180 K

b) The absorption features between 14-16 um correspond to absorption by CO_2, whereas

4 those between 9-10 um correspond to absorption by O_3.

c) In panel (c) the surface is colder than the region of the atmosphere from which

4 the 15 um radiation is emerging, so the feature looks like a "bump" rather than a "dip" in the spectrum.

d) $T_{surface} = 280K$, T for 15 um = 220K

$\Rightarrow \Delta T = 280K - 220K = 60K$

4 $\Delta z = 60K / 6.5K\,km^{-1} = \boxed{9\ km}$

2

Since terrestrial radiation is not important,

2) equilibrium will reflect a balance between Solar radiation and emission from the satellite

power absorbed $= S_0 \pi r^2$

power emitted $= 4\pi r^2 \sigma T^4$

Note albedo $= 0$ since it is a blackbody.

$$S_0 \pi r^2 = 4\pi r^2 \sigma T^4$$

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$$T = \left[\frac{S_0}{4\sigma}\right]^{1/4}$$

When the satellite goes into Earth's shadow it will lose energy at the rate $4\pi r^2 \sigma T^4$

$\Rightarrow$ for mass $m = 10^3$ kg and specific heat c

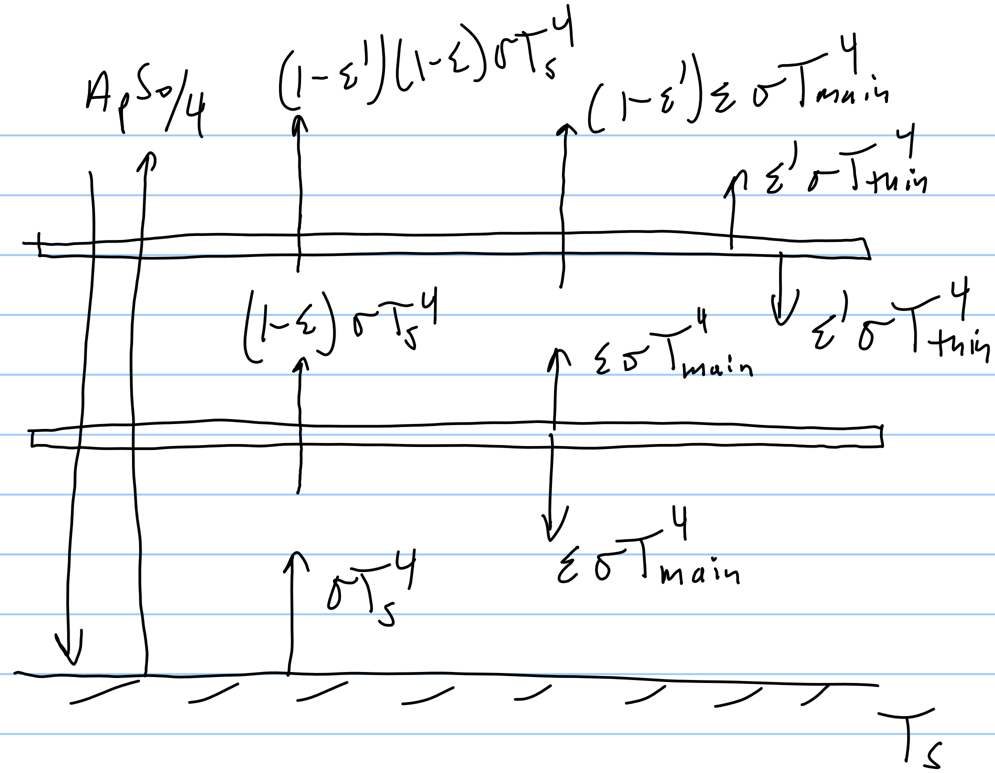
$$\text{energy loss} = mc\frac{dT}{dt} = 4\pi r^2 \sigma T^4$$

$$\Rightarrow \quad mc\frac{dT}{dt} = \pi r^2 S_0$$

$$\Rightarrow \quad \frac{dT}{dt} = \frac{\pi r^2 S_0}{mC} = \frac{\pi (1\,m)^2 (1370\ W m^{-2})}{10^3\ kg\ (10^3\ J\ kg^{-1}\ K^{-1})}$$

$$\boxed{\frac{dT}{dt} = 4.3 \times 10^{-3}\ K/s = 15.5\ K/hr}$$

3)



<u>Top of atmosphere</u>

$$\frac{S_0}{4}(1-A_p) = (1-\varepsilon')(1-\varepsilon)\sigma T_s^4 + (1-\varepsilon')\varepsilon\sigma T_{main}^4 + \varepsilon'\sigma T_{thin}^4 \qquad (1)$$

$$= (1-\varepsilon)\sigma T_s^4 + \varepsilon\sigma T_{main}^4 + \varepsilon'\sigma T_{thin}^4$$

Since $\varepsilon' \ll 1 \Rightarrow (1-\varepsilon') \simeq 1$

<u>Thin layer</u>

$$\underbrace{\varepsilon'(1-\varepsilon)\sigma T_s^4 + \varepsilon'(\varepsilon\sigma T_{main}^4)}_{\text{absorbed}} = \underbrace{2\varepsilon'\sigma T_{thin}^4}_{\text{emitted}}$$

$$(1-\varepsilon)\sigma T_s^4 + \varepsilon\sigma T_{main}^4 = 2\sigma T_{thin}^4 \qquad (2)$$

insert (2) into (1)

2D

$$\Rightarrow \frac{S_0}{4}(1-A_p) = 2\sigma T_{thin}^4 + \varepsilon' \sigma T_{thin}^4$$
$$= (2+\varepsilon')\sigma T_{thin}^4$$
$$\approx 2\sigma T_{thin}^4$$

but $\frac{S_0}{4}(1-A_p) = \sigma T_e^4$

$$\Rightarrow \quad \sigma T_e^4 = 2\sigma T_{thin}^4$$

$$\Rightarrow \quad \boxed{T_{thin} = \frac{T_e}{2^{1/4}} = \frac{255K}{2^{1/4}} = 214\ K}$$

This is the coldest temperature since this layer is heated from below only, unlike the main layer which is heated from below and above.