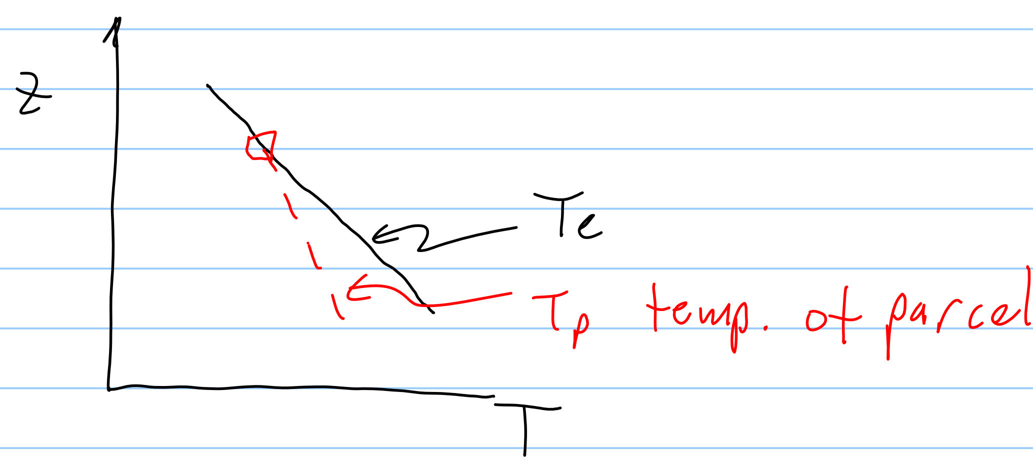
PHY392 Midterm Exam Solutions 2014

1) a) No, you cannot tell. Since the heating rates are the same, in equilibrium, the rate of heat loss will be the same, so externally the two houses will appear the same. Internally, the better insulated house will have a higher temperature.

b) It will be unstable. As the parcel sinks it will warm more slowly than the environment, so it will be colder and more dense. Consequently, it will accelerate downward.



c) 9-10 um : absorption due to O_3.

14-16 um : absorption due to CO_2.

d) Assume T_s = 295 K (from atmospheric near 10-12 um) between 14–16 μm, the brightness temperature is T = 220 K

$\Rightarrow \Delta T = 295\,K - 220\,K = 75\,K$

$$\Delta z = \frac{75\,K}{6.5\,K/km} \Rightarrow \boxed{\Delta z = 11.5\ km}$$

e) $$T_e = \left[\frac{L_0(1-A_p)}{4\sigma}\right]^{1/4}$$

$$\frac{T_e'}{T_e} = \left[\frac{1-A_p'}{1-A_p}\right]^{1/4} = \left(\frac{1-0.1}{1-0.3}\right)^{1/4} = \left(\frac{0.9}{0.7}\right)^{1/4}$$

$$T_e' = 1.0648\,(255K) = 271.5K$$

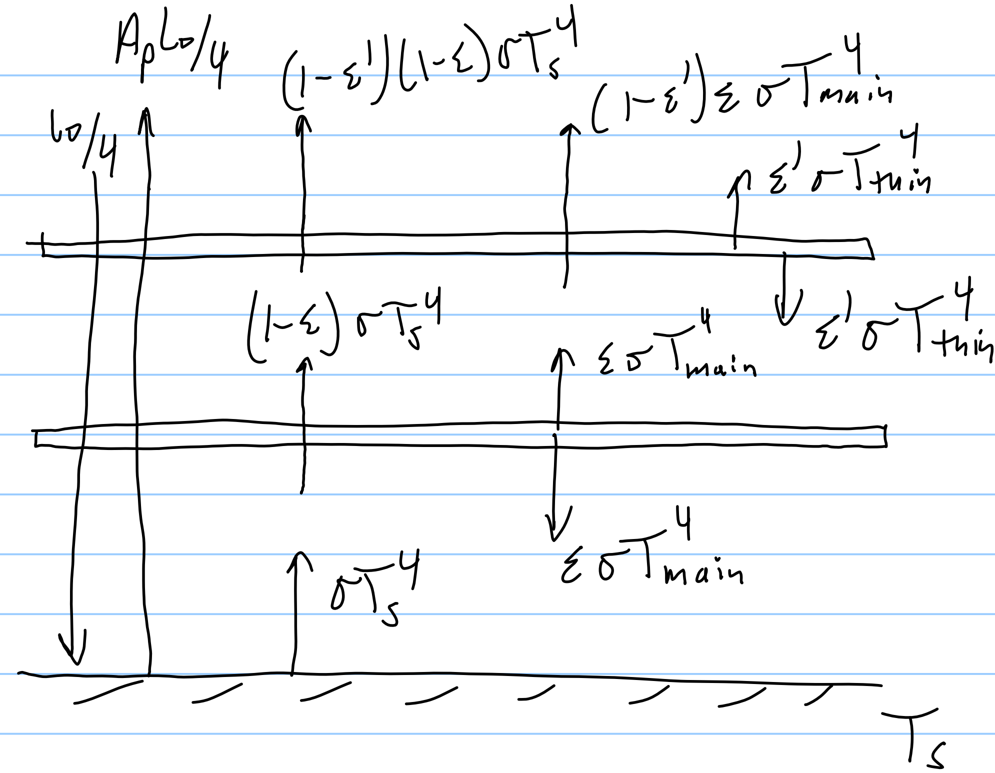
Te would increase by 16.5 K

f) By definition, Te is the effective temperature of the Earth required so that the outgoing longwave radiation balances the absorbed solar radiation:

$$\frac{L_0}{4}(1-A_p) = \sigma T_e^4 \Rightarrow \text{does not depend on absorptivity}$$

$$\Rightarrow \boxed{\Delta T_e = 0}$$

2)



Top of atmosphere

$$\frac{L_0}{4}(1-A_p) = \sigma T_e^4 = (1-\varepsilon')(1-\varepsilon)\sigma T_s^4 + (1-\varepsilon')\varepsilon\sigma T_{main}^4 + \varepsilon'\sigma T_{thin}^4 \quad (1)$$

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

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

Thin layer

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

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

insert (2) into (1)

$$\Rightarrow \sigma T_e^4 = 2\sigma T_{thin}^4 + \varepsilon' \sigma T_{thin}^4$$

$$= (2+\varepsilon')\sigma T_{thin}^4$$

$$\simeq 2\sigma T_{thin}^4$$

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

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

This is the coldest temperature since this layer is heated from below only, unlike the main layer which is heated from below and above, and absorbs only a small fraction of the incident infrared radiation.