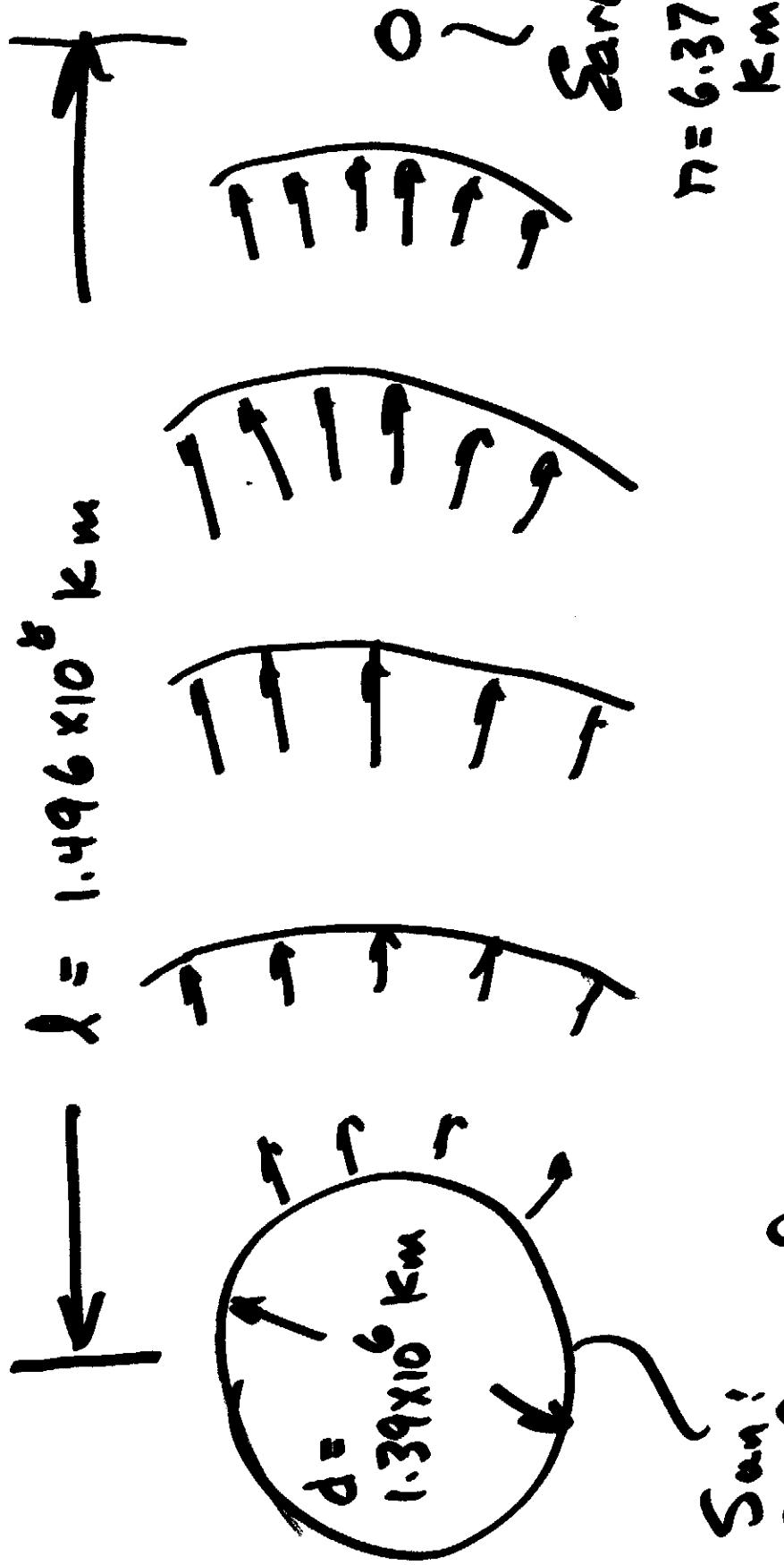


Lecture 4

①



②
Sun:
Surface of
Sun approximated by
radiating gas as
a blackbody of

$$T \approx 5800 \text{ K}$$

$$\sigma T_s^4 \pi d_s^2 = G_0^* 4\pi l^2$$

$$G_0^* = \sigma T_s^4 \left(\frac{d_s}{2l} \right)^2$$

$$= 5.67 \times 10^{-8} \frac{W}{m^2 \cdot K^4} \times (5800 K)^4$$

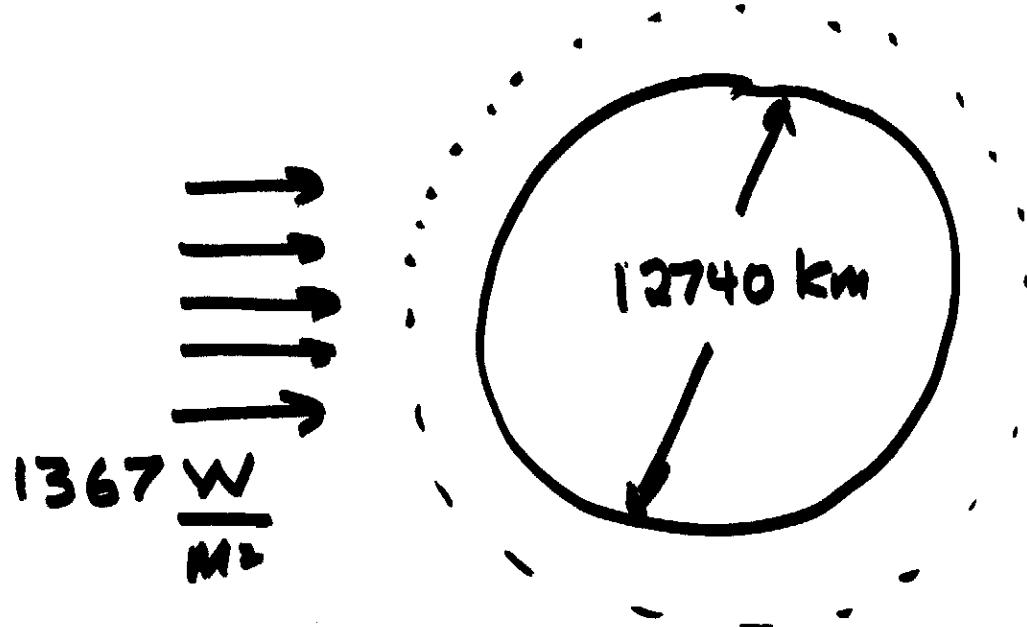
$$\times \left(\frac{1.39 \times 10^6 \text{ km}}{2 \times 1.496 \times 10^8 \text{ km}} \right)^2$$

$$= 1385 \frac{W}{m^2}$$

Using more accurate value
for T_s gives textbook
value of

$$G_0^* = 1367 \frac{W}{m^2}$$

This is the energy/sec-area
striking the edge of the
earth's atmosphere.



Rays are almost straight,
i.e. parallel, since earth
is far from sun.

The total energy/s received by the earth at any instant is

$$G_0 \times \frac{\pi}{4} d_e^2$$

$$= 1367 \frac{W}{m^2} \times \frac{\pi}{4} \times (1.274 \times 10^7 m)^2$$

$$= 1.74 \times 10^{17} W$$

$$\text{One terawatt} = 10^{12} W$$

Thus total energy/s is about 170,000 TW

3

Due to the eccentricity of the earth's orbit, G_0^* is slightly greater in December and slightly less in June.

The variation in G_0^* over the year is about $\pm 3\%$.

When the sun is overhead directly (90°) the maximum energy sec-area reaching the surface on a very clear day is $1000 - 1100 \frac{W}{m^2}$

(Note: PV equipment is rated at a solar energy/s-area input of 1000 W/m²)

Suppose we average our 1367 W/m² value over the earth:

$$\frac{G_0^* \frac{\pi d_e^2}{4}}{\pi d_e^2} = \frac{G_0^*}{4}$$

$$= 342 \frac{W}{m^2}$$

This value is averaged over night and day, over all parts of the earth, over all seasons

About 30% of the sunlight
is reflected to space
by the earth and its
atmosphere --
this is the albedo of
the earth. The breakdown
is : 8% reflection by air
17% reflection by clouds
6% reflection by surface

$$342 \times .7 = 240 \frac{W}{m^2}$$

average solar
energy/s-area
absorbed by the
earth and its
atmosphere

On average, The sunlight
is absorbed as follows:

19% (of 342 W/m^2)

by gases and dust in
atmosphere

4% (of 342 W/m^2)

by clouds

46% (of 342 W/m^2)

by surface of earth

Thus, on average,
the earth's surface
absorbs

157 W/m^2

This is
averaged
over night &
day, over
all seasons,
over all parts
of earth.

Regions of the globe that receive 300 W/m^2 on average are very sunny.

Text, Fig 1.2, shows 50,000 TW reflected.

Check : $\frac{50,000 \text{ TW}}{170,000 \text{ TW}} \approx 0.30$

Thus, 120,000 TW is absorbed

Text says 80,000 TW heats the earth's surface.

Check : $\frac{80,000}{170,000} = 0.47$

Let's complete our balance of the earth's energy.

So far, we know that 157 W/m^2 of solar radiation is absorbed by the earth's surface.

For equilibrium, this has to be balanced by the energy/s leaving the earth's surface.

The average temperature of the earth's surface is about 288K .

Thus, the long wavelength (infrared = IR) energy/s leaving the earth's surface

is :

$$\sigma T_{\text{sur}}^4 = 390 \text{ W/m}^2$$

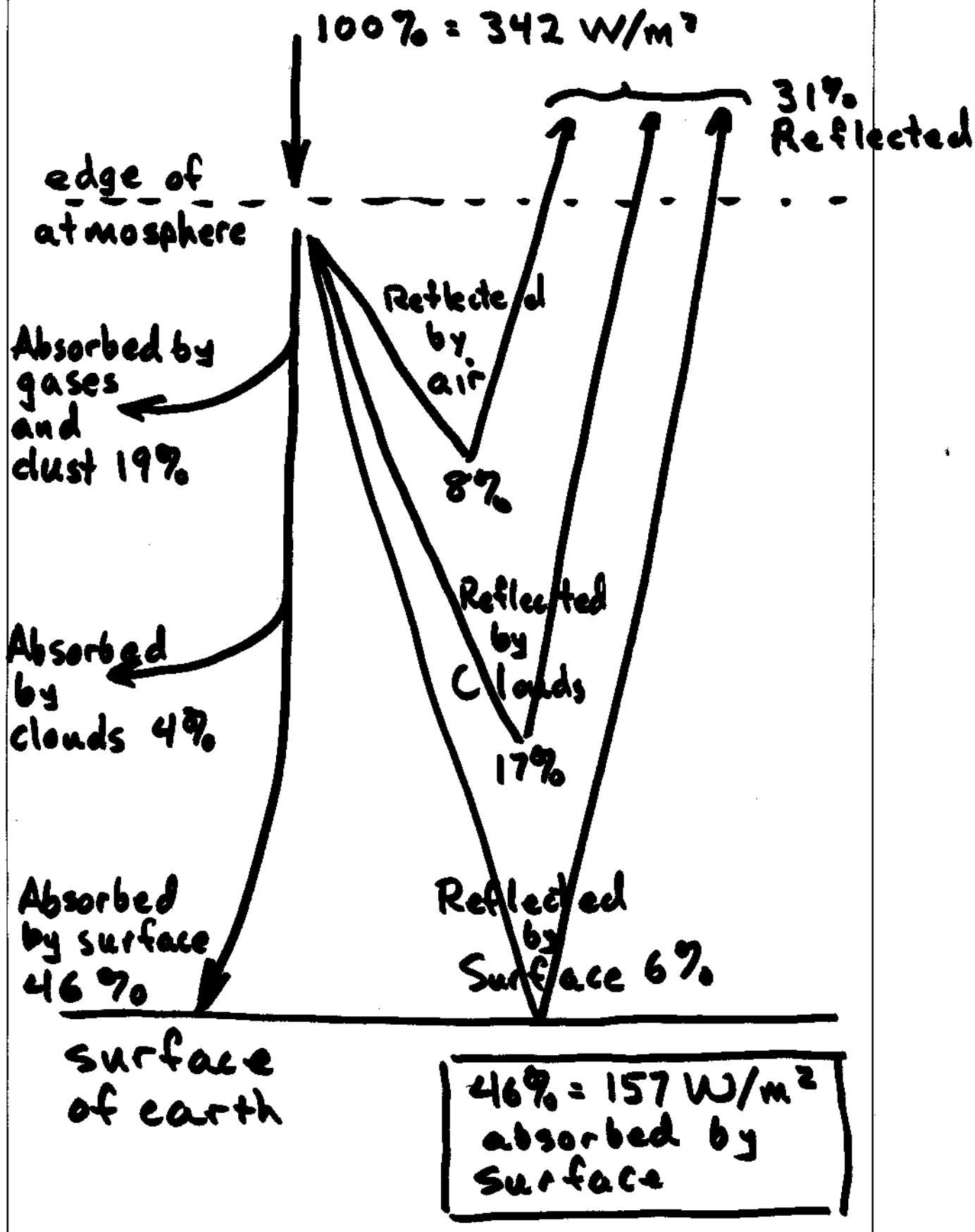
This corresponds to about 115% of incoming solar radiation, i.e.

$$\frac{390}{342} \times 100 \approx 115\%$$

We appear to have more energy leaving (115%) than absorbed (46%).

We need more information. Full picture shown on next two pages

Short-wavelength solar radiation



Long-wavelength IR radiation

