When a cloud is dense enough with water droplets it appears fleecy white, it is also dense enough that it can cause a shadow. Scientists use the terms albedo and transmission to describe how clouds and other materials reflect and transmit light.

**Albedo:** The amount of light a cloud reflects, making it appear white.

**Transmission:** The amount of light that passes through a cloud to the ground.

Albedo and transmission can be conveniently measured in percentages. For example, in the figure to the left, if 100% of the light energy falls on the cloud and 70% is reflected back into space, the cloud albedo is 70% and the percentage of transmitted energy is 100% - 70% = 30%.

**Problem 1** – A cloud has an albedo of 65%, but a sensitive light meter registers only 30% transmitted light directly under the cloud. How much light energy has been absorbed by the cloud to heat it?

**Problem 2** – A satellite view of a small area of Earth from space shows that 1/6 of the area had soil cover with an albedo of 20%, 1/3 of the area was covered by clouds with an albedo of 60%, and 1/2 of the area covered by water with an albedo of 10%. What is the average albedo of this area?
Instead of transmission, scientists prefer to use the term opacity, $x$, because it can be more easily calculated from the actual properties of the cloud. For example, $x = kL$, where $L$ is the thickness of the cloud and $k$ is a constant that describes the density of droplets in the cloud and droplet sizes. Transmission, $T$, and opacity are related by the formula:

$$T = 100\% \times 10^{-0.69x}$$

**Problem 3** - Graph the function $T(x)$ for opacities from 0.0 to 5.0. To the nearest percentage, what is the range of cloud transmission and albedo for opacities covered by your graph?

**Problem 4** – A cumulus cloud is 2.5 kilometers thick and its opacity constant, $k = 0.5$, what is the albedo of this cloud, and how much light is transmitted through the cloud to the ground?
Common Core Math Standards:
CCSS.Math.Content.HSF-LE.A.2 Construct linear and exponential functions, including arithmetic and geometric sequences, given a graph, a description of a relationship, or two input-output pairs (include reading these from a table).

CCSS.Math.Content.HSF-LE.A.4 For exponential models, express as a logarithm the solution to abct = d where a, c, and d are numbers and the base b is 2, 10, or e; evaluate the logarithm using technology.

Problem 1 – A cloud has an albedo of 65%, but a sensitive light meter registers only 30% transmitted light directly under the cloud. How much light energy has been absorbed by the cloud to heat it? Answer: With an albedo of 65%, 35% of the light energy should have reached the ground. Since only 30% was detected, that means that 5% of the light energy was absorbed by the cloud to heat it.

Problem 2 – A satellite view of a small area of Earth from space shows that 1/6 of the area had soil cover with an albedo of 20%, 1/3 of the area was covered by clouds with an albedo of 60%, and 1/2 of the area covered by water with an albedo of 10%. What is the average albedo of this area? Answer: A = 1/6 (20%) + 2/6(60%) + 3/6(10%) = 28%

Problem 3 - Graph the function T(x) for opacities from 0.0 to 5.0. To the nearest percentage, what is the range of cloud transmission and albedo for opacities covered by your graph?

Problem 4 – A cumulus cloud is 2.5 kilometers thick and its opacity constant, k = 0.5, what is the albedo of this cloud, and how much light is transmitted through the cloud to the ground?

Answer: x= kL so x= (0.5)(2.5) = 1.25 then the transmission T = 100% 10^{-0.69(1.25)}
Then T = 100%(0.137)
And so T = 13.7% and the albedo = 100% - 13.7% = 86.3%

Space Math http://spacemath.gsfc.nasa.gov