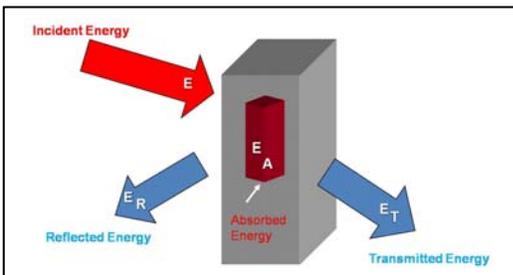




When a cloud is dense enough with water droplets it appears fleecy white, it is also dense enough that it can cause a shadow. Scientists use the terms albedo and transmission to describe how clouds and other materials reflect and transmit light.

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:

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

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:

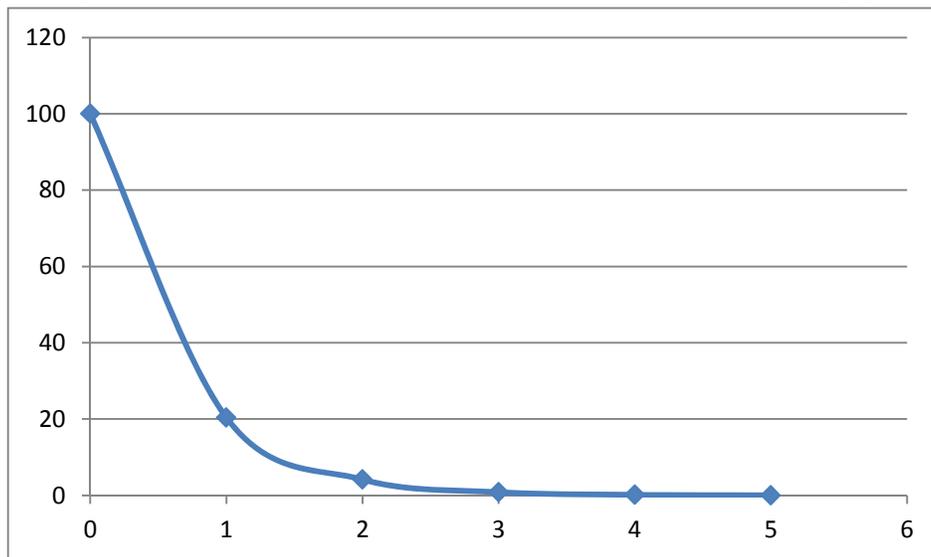
CCSS.Math.Content.HSF-LE.A.2 Construct linear and exponential functions, including arithmetic and geometric sequences, given a graph, a description of a relationship, or two input-output pairs (include reading these from a table).

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: $A = 1/6 (20\%) + 2/6(60\%) + 3/6(10\%) = \mathbf{28\%}$

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?



Opacity 1 to 5 Transmission: 20% to 0% Albedo: 80% to 100%

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 $T = \mathbf{13.7\%}$ and the albedo = $100\% - 13.7\% = \mathbf{86.3\%}$