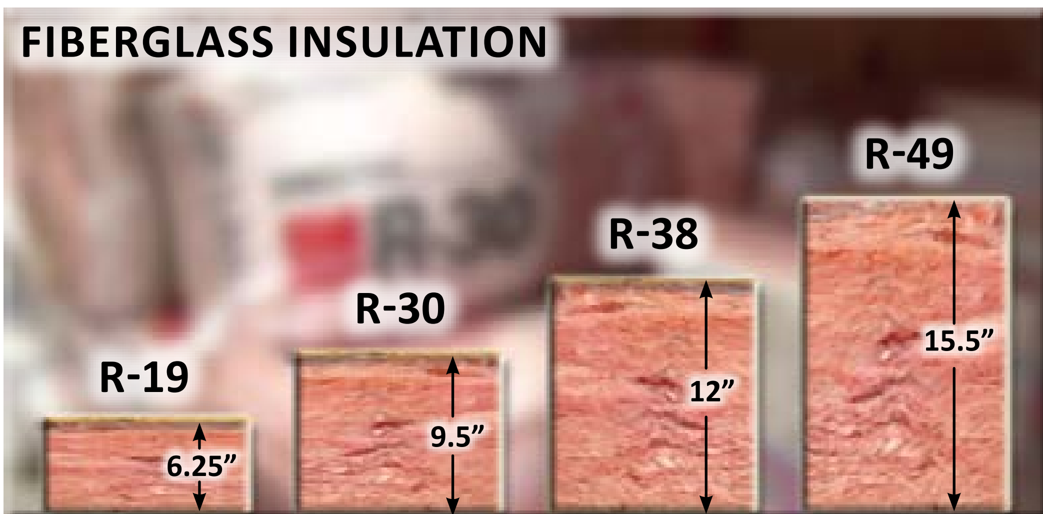
KSB* 3

(*KNOWLEDGE AND SKILL BUILDER)

RELATIONSHIP BETWEEN K VALUE AND R VALUE



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Hofstra University Center for Technological Literacy
Simulations and Modeling for Technology Education

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IN THIS KSB, EACH OF THE FOLLOWING KEY IDEAS WILL BE EXPLAINED CLEARLY; FOR NOW, JUST READ THEM OVER BRIEFLY.

1. k value and R value are both measures of a material's resistance to heat flow. k value relates only to the type of material where R value also takes into account the material's thickness (L).
2. Since R value takes thickness (L) into account, yet is related to k value, **R, L, and k can be expressed in a relationship**. The R value of a material equals its thickness / its k value (**R=L/k**).
3. The total R value (Rt) of a system of materials is the sum of each of the individual R values (Rt = R1+ R2+ R3 +R....)

In the prior KSB, you learned that the formula that you use to calculate the rate of heat transfer from hot to cold is **$Q = kA(\Delta T) / L$**. You remember that one of the factors that influences the rate of heat flow is the thermal conductivity of the material that is being used as a conductor or an insulator of heat. Normally, the outside surfaces of our houses or apartment buildings are made from more than one type of material. A wall, for example, can be made from sheetrock (plasterboard) on the inside, brick and plywood on the outside, and some kind of insulation, perhaps fiberglass between the inside and outside surfaces (*Figure 1*).

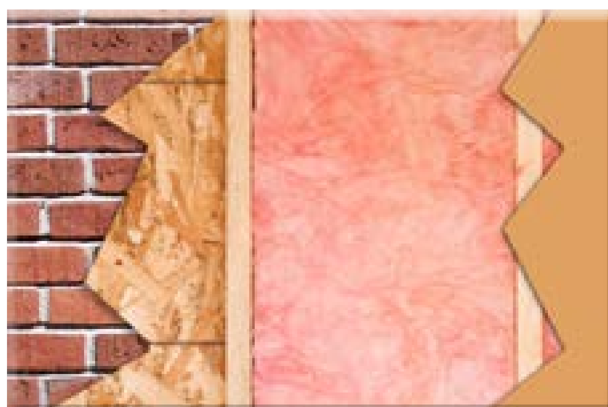


***Figure 1*: Insulated wall consisting of (from outside in); brick, plywood, 2X6 framing, fiberglass insulation, and drywall**

In the case where several different materials are used in combination to limit heat transfer from the warm inside to the cold outside, we would have to figure out what the k value of the combination of materials is. That is not a trivial problem.

However, there is an easy solution. When you buy insulating materials at a home center or hardware store, you don't ask for a material by its k value. Remember the k value relates to the type of materials, like Styrofoam™, or fiberglass. It has nothing to do with the material's thickness. A thick piece of fiberglass has exactly the same k value as a thinner piece. But we specify thickness when we buy materials: a 3 ½ inch batt of fiberglass; a sheet of Styrofoam™ 1 inch thick.

You know that thickness makes a big difference with regard to heat transfer. The heat transfer formula tells you that the greater the thickness (remember, L is in the denominator of the formula) the smaller is Q (the lower the rate of heat flow). And doesn't that make sense? A building made from very thick walls will retain internal heat better than a building made from very thin walls of the same material.

THINK LIKE AN ENGINEER

R VALUE

Life is getting easier. Let's introduce R value. R value is a measure of how well a piece of material resists the flow of heat through it. k value and R value are both measures of a material's resistance to heat flow. k value relates only to the type of material where R value also takes into account the material's thickness. A piece of material that is twice as thick as another piece of the same material has twice the R value.

If you buy insulation (*Figure 2*), you will see insulation materials rated by their R-value. For example, a 3 ½" batt of fiberglass has an R value of 13. A one-inch thick piece of Styrofoam™ has an R value of 5. What would be the R value of a two-inch thick piece of Styrofoam™?

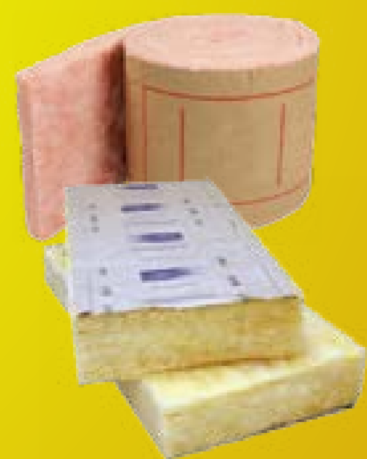


***Figure 2*: Roll of insulation (top), batts* of insulation (bottom)**

R =______

Since k and R values are related to one another and R takes thickness to account, R can be expressed in terms of L and k.

The R value of a material equals its thickness / its k value. (**R = L/k**).

*A batt is precut strips of insulation available in various widths

CHECK YOUR UNDERSTANDING

Let's do some simple calculations:
If you know the k value of a material and you know its thickness, let's find the R value. Calculate the follow R valves below.

Write your answer in the far right column.

Remember!

R=L/k (and don't forget that L, thickness, is in feet, not inches).
One inch = 1/12 foot or 0.08333 feet.

Material	Thickness in inches	Thickness in feet (L)	k value	Calulate R value (use L/k)
Aluminum	1/4"	0.25/12 = 0.02	144.5	
Brick	4"	4/12 = 0.333	0.41	
Fiberglass Batt	3.5"	3.5/12 = 0.29	0.019	
Stone	4"	4/12 = 0.333	1.04	
Plywood	1"	1/12 = 0.0833	0.075	

Now using the relationship between R, L, and k, watch what happens to our heat flow formula. We start with the original heat flow formula:

$$Q = k\,A\,(\Delta T) / L$$

Do you see that we have a k/L term in our heat flow formula? Remember that **R = L/k**; therefore, 1/R = k/L (invert both terms).

Since 1/R = k/L, just substitute 1/R for k/L and now our formula becomes simpler:

$$Q = \frac{k\,A\,(\Delta T)}{L} = \frac{1\,A\,(\Delta T)}{R}$$

Now, Q simply becomes Q = A (ΔT) / R

Using the above formula, redo the problem you did in KSB 2E, using R instead of k and L. That is, find the number of BTU/hour that will be necessary to maintain an inside temperature of 70° F if the outside temperature is 25° F. Assume a cubic structure 6' on each side (remember, we only are considering five sides, not the bottom) and that the structure is made of plywood that is 1" thick.

(You figured out the R value for 1" thick plywood a moment ago in your sample R value calculations. You probably found that plywood that is 1" thick has an R value of 1.1106).

Using R is easier than using k and L:

Q = A (ΔT) / R
Q = 5*6*6 (45) / 1.1106
Q = 7293 BTU/hour

If we know the R value of a piece of material, we don't have to worry about the thickness or the k value in figuring out how heat flows through it. A great thing about using R value is that no matter how many materials we place in combination, one on top of the other, **we just add their individual R values** to get the total R value.

The total R value (R_t) of a system of materials is the sum of each of the individual R values ($R_t = R_1 + R_2 + R_3 + R....$)

CHECK YOUR UNDERSTANDING

Figure out the R_t (Total R Value) of the following combinations of materials.
Write your answer in the far right column.

Material 1	R1	Material 2	R2	Material 3	R3	Total R Value
1" Polyurethane Foam	6.9	1" Styrofoam™	4.8	1" Cork	2.08	
1/16" Cardboard	0.64	1" Polyethylene Foam	4.38	1" Straw	1.6	
1" Cork	2.08	1/16" Cardboard	0.64	1" Styrofoam™	4.8	

MATH AT WORK:

Heat flow through a wall In this diagram of a wall section (*Figure 3*), the total R value of the wall would be the R values of the exterior sheathing, the foam core insulation, and the interior sheathing all added together.

If the exterior sheathing is made from ½" plywood (R=0.55), the core is made from 1" of Styrofoam™ (R=4.8), and the interior sheathing is made from hardboard (masonite) (R=0.24), the total R value of the wall system would be: 0.55 + 4.8 + 0.24 = 5.59.

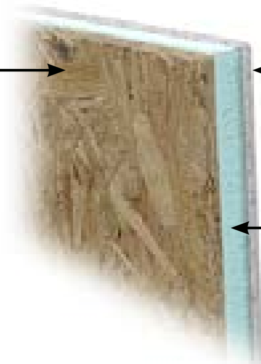


***Figure 3*: Wall section**

In using the heat flow formula to calculate heat flow through the wall ($Q = A (\Delta T) / R$), you'd use 5.59 as the value for R in the denominator.

CHECK YOUR UNDERSTANDING

Answer the follow questions.

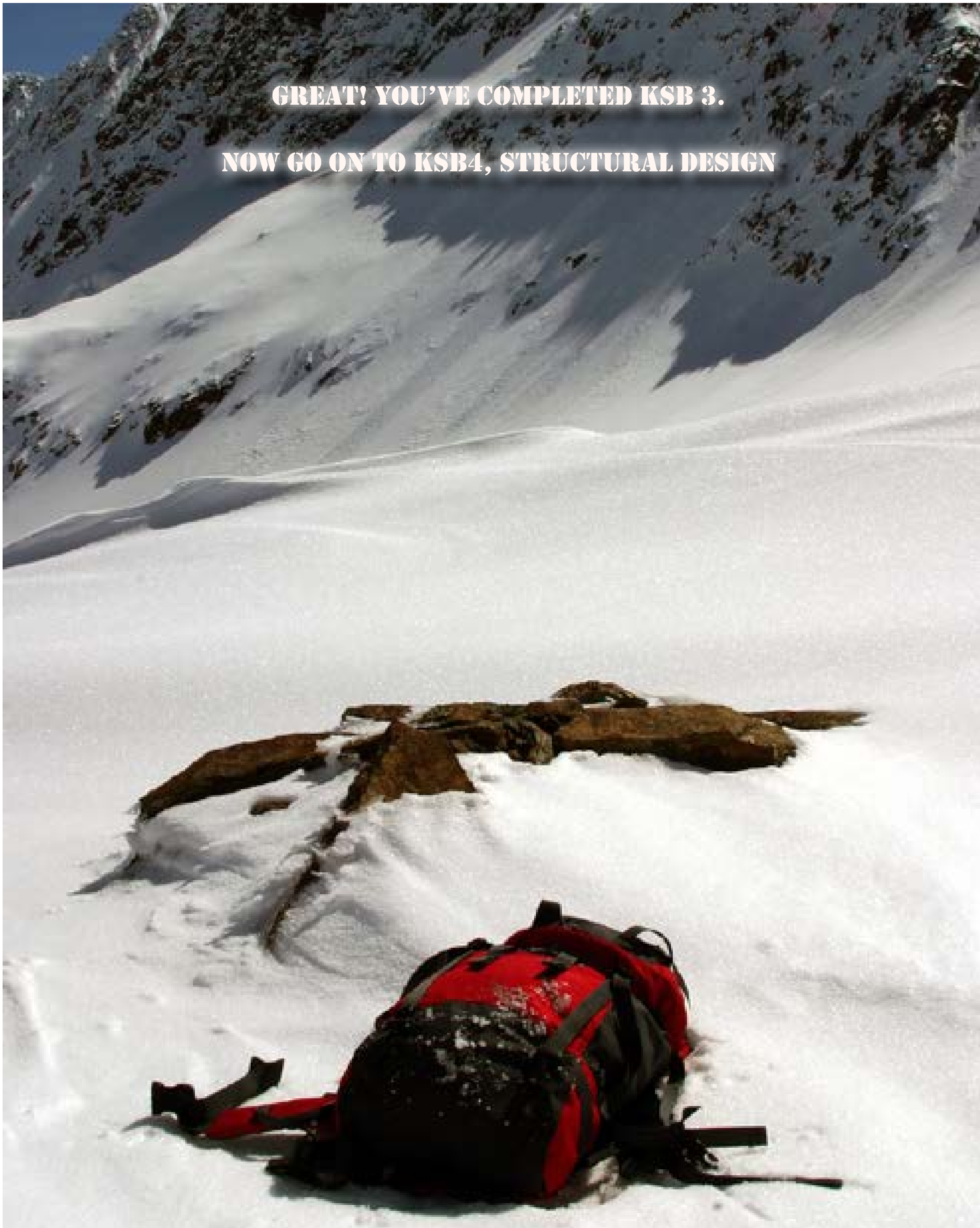
1. Of the materials used above which has the highest R value?

   ____

2. Of those same materials, which has the highest k value?

   ____

	(Check one) YES	NO
3. Would ½" thick aluminum have the same R value as ¼" thick aluminum?	☐	☐
4. Would ½" thick aluminum have the same k value as ¼" thick aluminum?	☐	☐


GREAT! YOU'VE COMPLETED KSB 3.
NOW GO ON TO KSB4, STRUCTURAL DESIGN