Math Concepts for BPI - EA Exam

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Examples, Solutions, and Problems

Unit I: AREA & VOLUME

1. Square feet (surface area) of wall, floor, window, or door:

Multiply length x width or (base x height).

Example 1: What is the surface area of a wall that is 12 feet long and 8 feet high?

Solution: Multiply the dimensions:

8’ x 12’ = **96 square feet**

Example 2: What is the surface area in square feet of a window that is 3 feet wide and 28 inches tall?

Solution: Convert both numbers to the same units first. Use the units you want the answer to be in, such as square feet. 28 inches is the same as 28” ÷ 12 = 2.33’. The question becomes, “What is the surface area of a window that is 3 feet x 2.33 feet?” The solution is to multiply them:

3’ x 2.33’ = **6.99** or **7 square feet**

Example 3: What is the surface area in square inches of a window that is 3 feet wide and 28 inches tall?

Solution: Convert both numbers to the same units. Let’s use inches this time (3 feet is the same as 3 x 12 = 36 inches). The question becomes, “What is the surface area of a window that is 36 inches by 28 inches? The solution is to multiply them:

36” x 28” = **1,008 square inches**

If you ever need to change square inches back to square feet, convert as follows: You have to divide by 12 for each measurement that started out in inches. In this case, we used 36 inches and 28 inches, so we have to divide the answer by 12 twice.

For example, since our answer is 1,008 square inches, we have to divide 1,008 ÷ 12 = 84, then divide again: 84 ÷ 12 = 7 square feet. Alternatively, you could simply divide by 144 (inches in a square foot) to arrive at square feet.

Problem 1: What is the surface area of a wall that is 22 feet long and 9 feet high?

Problem 2: What is the surface area of a window that is 16 inches x 36 inches?

Problem 3: What is the surface area of a wall, excluding windows, if the wall is 12 feet long and 8 feet high and has a window that is 2 feet by 42 inches?

Problem 4: What is the surface area of a typical door that is 6 feet 8 inches tall and 30 inches wide? (Round off to 1 decimal place)

Problem 5: What is the surface area of a wall, excluding doors and windows, if the wall is 22 feet long.

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2. Surface area of a 3-dimensional form:

Find the area of each surface individually, then add them all together.

Example 1: What is the surface area of the walls of a room if the room is 10 feet x 12 feet x 8 feet high?

Solution: First you have to figure out what each wall looks like. There are two long walls and two short walls. The long walls are 12 feet long and 8 feet high. The short walls are 10 feet long and 8 feet high.

Find the surface area of the long walls first: 12’ x 8’ = **96 square feet**.

Then find the surface area of the short walls: 10’ x 8’ = **80 square feet**.

There are four walls, so add their surface area together: 96 + 96 + 80 + 80 = **352 square feet**

Example 2: What is the surface area of the walls, floor, and ceiling of a room if the room is 10 feet x 12 feet x 8 feet high?

Solution: We have already figured out the surface area of the walls above, but now we have to include the floor and ceiling too.

Figure out which dimensions give you the floor area. In this case, the room is 10 feet x 12 feet, so we should multiply 10’ x 12’ = 120 square feet.

The ceiling has the same surface area as the floor. Now we have to add all the surfaces together:

96 + 96 + 80 + 80 + 120 + 120 = **592 square feet**

Problem 1: What is the surface area of the walls of a room that is 20 feet long and 14 feet wide and has a 10 foot ceiling?

Problem 2: What is the surface area of the walls, floor, and ceiling of a room that is 13 feet wide, 21 feet long, and has an 8 foot ceiling?

3. Volume of room or rectangular cavity:

Multiply square feet of floor area by average ceiling height (length x width x height)

Example 1: What is the volume of a box that has the following dimensions: 4 inches wide x 10 inches long x 6 inches tall?

Solution: Multiply 4" x 10" x 6" = **240 cubic inches**

Example 2: What is the volume of a box that has the following dimensions: 1 foot wide x 60 inches long x 10 inches tall?

Solution: Convert all to the same units first. Let's use feet. 60 inches is the same as 60" ÷ 12 = 5' and 10 inches is the same as 10" ÷ 12 = 0.833'). The problem becomes: What is the volume of a box that has the following dimensions: 1' x 5' x 0.833'

Multiply 1' x 5' x 0.833' = **4.2 cubic feet**

Alternate Solution: In this problem, it might be easier to use inches. 1 foot is the same as 12 inches. The problem becomes: What is the surface area of a box that has the following dimensions: 12 inches x 60 inches x 10 inches.

Multiply 12" x 60" x 10" = **7,200 cubic inches**

If you need the answer to be in cubic feet, convert as follows: You have to divide by 12 for each measurement that started out in inches. In this case, we used 12 inches, 60 inches, and 10 inches, so we have to divide the answer by 12 three times. For example, our answer was 7,200 cubic inches. So, we have to divide 7,200 ÷ 12 = 600, then divide again 600 ÷ 12 = 50, then divide again 50 ÷ 12 = **4.2 cubic feet**

Example 3: What is the interior volume of a cavity that is 16 inches wide, 4 inches deep, and 8 feet tall?

Solution: Convert all to the same units first.

If using feet, multiply (16" ÷ 12) x (4" ÷ 12) x 8' = **3.6 cubic feet**

If using inches, multiply 16" x 4" x (8 x 12") = **6,144 cubic inches**

To convert back to cubic feet, divide by 12 three times: 6,144 ÷ 12 ÷ 12 ÷ 12 = **3.6 cubic feet**

Problem 1: What is the volume of a mechanical room that is 4 feet by 6 feet by 8 feet tall?

Problem 2: What is the volume of a laundry room that is 8 feet by 64 inches by 10 feet tall?

Problem 3: What is the volume of a wall cavity that is 20 inches wide by 6 inches deep by 8 feet tall?

4. Amount of insulation needed to fill a cavity to 3.5 pounds per cubic foot:

3.5 pounds per cubic foot is for dense pack cellulose.

Determine the volume of the cavity in cubic feet, then multiply by 3.5.

Example 1: How many pounds of insulation is needed to dense pack a wall cavity that is 16 inches wide, 4 inches deep, and 8 feet tall? We normally ignore framing.

(Converted to inches or feet first, as desired).

If using feet, multiply (16" ÷ 12) x (4" ÷ 12) x 8′ = **3.6 cubic feet**

If using inches, multiply 16" x 4" x (8′ x 12) = **6,144 cubic inches**

6,144 ÷ 12 ÷ 12 ÷ 12 = **3.6 cubic feet**.

Now, to figure out how much insulation we need to reach "dense pack", it is important to know that there must be 3.5 pounds of insulation per cubic foot of space. So, we multiply our final answer in cubic feet by 3.5. pounds per cubic foot.

Our answer was 3.6 cubic feet, so multiply 3.6 x 3.5 = 12.6. This answer tells us we need **12.6 POUNDS** of cellulose. (Never choose an answer that is LESS than your calculated total. Always round UP so you have enough to meet the minimum required.)

Example 2. How many bags of insulation are needed to dense pack a wall cavity that is 6 inches by 20 inches by 10 feet, if a bag holds 25 pounds of insulation?

Solution: First find the volume of the wall cavity. Multiply the three dimensions (converted to inches or feet first, as desired)

Using feet: (6" ÷ 12) x (20" ÷ 12) x 10′ = **8.3 cubic feet**

Using inches: 6" x 20" x (10′ x 12) = **14,400 cubic inches**

14,400 ÷ 12 ÷ 12 ÷12 = **8.3 cubic feet**

Now, to figure out how much insulation we need to reach "dense pack", it is important to remember that there must be 3.5 pounds of insulation per cubic foot of space. So, we multiply our final answer in cubic feet by 3.5 pounds per cubic foot.

Our answer was 8.3 cu. ft., so multiply 8.3 x 3.5 = 29.05, which rounds off to 29 POUNDS of cellulose. To figure out how many bags we need, we divide the final pounds by 25 pounds per bag.

So, 29 ÷ 25 = 1.16. This answer tells us we need at least 1.16 BAGS. Since we buy whole bags, round up to **2 bags**.

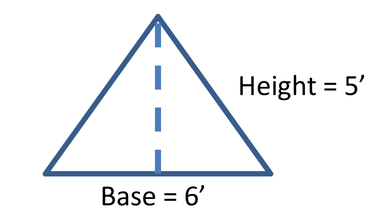
Problem 1: How many pounds of insulation is needed to dense pack a wall cavity that is 16 inches wide, 6 inches deep, and 9 feet tall?

Problem 2: How many bags of insulation are needed to dense pack a wall cavity that is 10 inches by 20 inches by 10 feet, if a bag holds 25 pounds of insulation?

5. Area of a triangle:

½ x base x height

Example 1: What is the area of the triangle below?

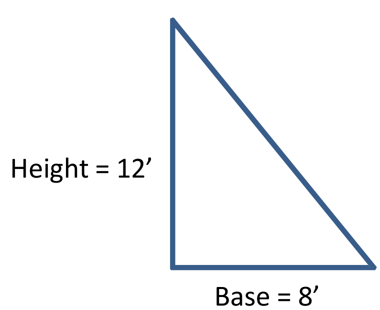


Solution: Multiply the base x height and divide it by 2. In this case base = 6 feet and height = 5 feet, so we multiply 6 x 5 = 30. Divide the result by 2 to get 15. This looks like the following:

½ x base x height = Area

½ x 6’ x 5’ = **15 square feet**

Example 2: What is the area of the triangle below?



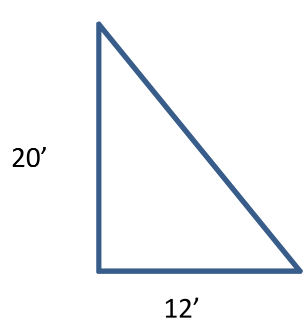
Solution: Multiply the base x height and divide it by 2. In this case base = 8 feet and height = 12 feet, so we multiply 8 x 12 = 96. Divide the result by 2 to get 48. This looks like the following:

½ x base x height = Area

½ x 8’ x 12’ = **48 square feet**

Problem 1: What is the area of a gable end if the distance across the base is 25 feet and the maximum height of the attic is 5 feet?

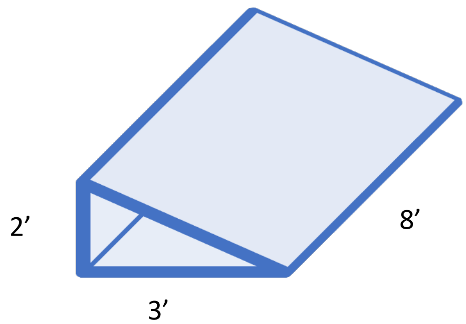
Problem 2: What is the square footage of a triangular porch if it has the following dimensions:



6. Volume of a triangular space:

½ x length x width x height or (½ x base x height x length)

Example 1: What is the volume of a triangular space if the base of the triangle is 3 feet, the height of the triangle is 2 feet and the length is 8 feet long?



Solution: The formula is ½ x length x width x height or (½ x base x height x length). The order of the three dimensions doesn’t matter. You just need to find all three dimensions and multiply them, then divide the result by 2.

In this case, we have 3 dimensions: 3’ x 2’ x 8’ = 48 cubic feet. Divide this result by 2 to get 24 cubic feet. This looks like the following:

½ x 3’ x 2’ x 8’ = **24 cubic feet**

Example 2: What is the volume of an attic if the floor of the attic is 20 feet x 40 feet and the highest point of the attic is 6 feet?

Solution: Find and multiply the three dimensions, in this case, 20’ x 40’ x 6’ = 4,800 cubic feet. Then divide the result by 2 to get 2,400 cubic feet. This looks like the following:

½ x 20’ x 40’ x 6’ = **2,400 cubic feet**

Problem 1: What is the volume of an eave closet (the roof slopes down to the floor) if it is 4 feet deep, 5 feet tall, and 20 feet long?

Problem 2: What is the volume of an attic CAZ (combustion appliance zone) if the width of the attic is 40 feet, the length is 60 feet and the maximum height is 7 feet?

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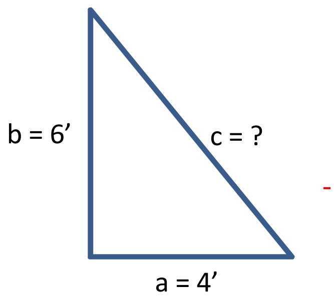
7. Third side of a right triangle (Pythagorean Theorem):

$a^2 + b^2 = c^2$

Example 1: What is the length of the third side of a right triangle if it has the following dimensions?

Solution: In the formula, there are 3 letters: a, b and c. The letter c always refers to the long side of the right triangle. To find out what c is, replace "a" and "b" in the formula with your numbers.

When you find the value of "c^2", you need to take the square root in order to find the value of "c". This usually requires a calculator.



$a^2 + b^2 = c^2$

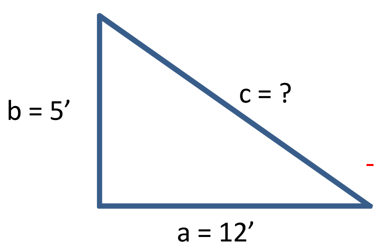
$4^2 + 6^2 = c^2$

$16 + 36 = c^2$

$52 = c^2$

$c = \sqrt{52} = \mathbf{7.2'}$

Example 2: What is the length of the third side of a right triangle if it has the following dimensions?



$a^2 + b^2 = c^2$

$12^2 + 5^2 = c^2$

$144 + 25 = c^2$

$169 = c^2$

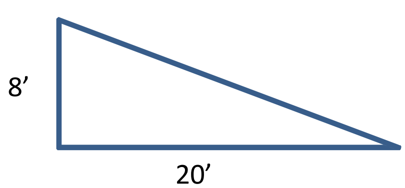
$c = \sqrt{169} = \mathbf{13'}$

Solution: As in the previous example, to find out what "c" is, replace "a" and "b" in the formula with your numbers, as seen above. Notice that it doesn't matter which number is "a" and which one is "b".

Remember, when you find the value of "c^2", you need to take the square root to find the value of "c". This usually requires a calculator.

Problem 1: Find the length of a sloped attic roof if the height of the attic is 6 feet and the distance from the eave to the center of the attic (a right triangle) is 12 feet.

Problem 2: To find out the slope of a roof to determine how many solar panels will fit top to bottom, we need to find the length of the slope from peak to end. If the peak is 8 feet above the attic floor and the end is 20 feet horizontally from the peak, what is the length of the slope?



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8. Height of the rise based on slope and run:

Ratio of the Slope x Run = Rise

Example 1: What is the rise when the ratio of the slope is 4:12 and the run is 12 feet?

Solution: Ratio of the Slope x Run = Rise

4 ÷ 12 x 12' = **4 feet**

Example 2: What is the rise when the run is 22 feet and the ratio of the slope is 6:12?

Solution: Ratio of the Slope x Run = Rise

6 ÷ 12 x 22' = **11 feet**

Example 3: What is the rise when the run is 10 feet and the ratio of the slope is 2:12?

Solution: Ratio of the Slope x Run = Rise

2 ÷ 12 x 10' = **1.67 feet**

Problem 1: When the slope is 5:12 and the run is 18 feet what is the rise?

Problem 2: What is the rise when the slope is 7:12 and the run is 24 feet?

Problem 3: When the run is 15 feet and the slope is 20:12 what is the rise?

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9. Water fixture GPM:

Container gallons ÷ Seconds to fill x 60 Seconds = GPM

Container is ½ gallon, filled in 10 seconds, x 60 (to convert seconds to minutes) = GPM

0.5 ÷ 10 x 60 = **3 GPM**

Example 1: What is the GPM when filling a 2 quart container if it takes 14 seconds?

Note: 2 quarts is ½ gallon.

Solution:

0.5 ÷ 14 x 60 = **2.14 GPM**

Example 2: If it takes 22 seconds to fill a 1/3 gallon container what Is the GPM?

1 ÷ 3 ÷ 22 x 60 = **0.9 GPM**

Problem 1: If it takes 32 seconds to fill a 1 quart container what is the flow rate?

Problem 2: A one gallon container takes 30 seconds to fill, what is the GPM?

Problem 3: What is the GPM when a one gallon container is filled halfway in 28 seconds?

Unit II: R-VALUE AND U-VALUE

1. Total R-value:

Multiply the R-value per inch by the number of inches. Add the R-values of different materials that are stacked in the same assembly.

Example 1: What is the total R-value of 3 inches of Fiberglass batts if the rated R-value is R-3.1 per inch?

Solution: Multiply the R-value per inch by the number of inches.

3.1 x 3 = **R- 9.3**

Example 2: How many inches of loose fill cellulose is needed to reach a total R-value of R-30 if the rated R-value of the cellulose is R-3.7 per inch?

Solution: If you know the total desired R-value, you need to divide that by the R-value per inch to determine how many inches of insulation you need.

30 ÷ 3.7 = **8.1 inches**

Don't round down on insulation questions like this. You can install MORE than 8.1 inches, but not LESS because you will not have enough insulation to meet the minimum R-value.

Example 3: What is the total R-value of the insulation if there are 4 inches of loose cellulose blown over a layer of 3.5 inches fiberglass batts on the attic floor?

Solution: Find the R-value of each layer and add it together.

4 x 3.7 = 14.8

3.5 x 3.1 = 10.9

Add together: 14.8 + 10.9 = **R-25.7**

Problem 1: What is the total R-value of 3.5 inches of dense pack cellulose in a wall if the rated R-value is R-3.2 per inch?

Problem 2: How many inches of XPS (Extruded polystyrene insulation) should we attach to an attic hatch if we need to reach a minimum of R-38, and the XPS is rated at R-5 per inch?

Problem 3: What is the total R-value of wall insulation if it includes a 2 inch layer of Polyisocyanurate (R-7.2 per inch) and a layer of 5.5 inch Denim batts (R-3.4 per inch)?

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2. U-value and R-value:

U = 1 ÷ R and R = 1 ÷ U (U-values CANNOT be added; convert to R-values first).

Example 1: What is the U-value of ½ inch drywall if it has a total R-value of R-0.45?

Solution: Convert the R-value to the U-value (also called U-factor) by taking the reciprocal. That is: put 1 over the R-value to get the U-value.

1 ÷ 0.45 = **U-2.22**

Example 2: Determine the total R-value of a wall assembly based on the following information.

a) Wood Siding: R-0.79

b) Sheathing: R-0.58

c) Framing: R-4.45

d) Drywall: R-0.52

Solution: R-values can be added, so you simply add the layers together to get the total R-value.

0.79 + 0.58 + 4.45 + 0.52 = **R-6.34** (You can round off to R-6)

Example 3: Determine the total U-value of a wall assembly based on the following information.

a) Wood Siding: U-1.3

b) Sheathing: U-1.6

c) Insulation: U-0.08

d) Drywall: U-2.2

Solution: U-values cannot be added, so you must convert all values to R-values first:

	U	1 ÷ U =	R
Wood Siding	1.30	1 ÷ 1.30	0.77
Sheathing	1.60	1 ÷ 1.60	0.63
Insulation	0.08	1 ÷ 0.08	12.50
Drywall	2.20	1 ÷ 2.20	0.45
		R Total	14.35

Once you have determined the R-value, you can convert it back to U-values: 1 ÷ 14.35 = **U-0.07**

Problem 1: What is the U-value of insulated vinyl siding that has a total R-value of R-1.8?

Problem 2: What is the total R-value of the following wall assembly?

a) Vinyl Siding: R-0.61

b) Sheathing: R-0.78

c) Framing: R-4.5

d) Drywall: R-0.57

Problem 3: What is the total U-value of the following wall assembly?

a) Vinyl Siding: U-0.56

b) Sheathing: U-1.4

c) Insulation: U-0.05

d) Drywall: U-2.2

Unit III: ENERGY

1. Calculate kWh:

Watts x hours ÷ 1,000

Example 1: How many kWh are used by a 1,500-Watt space heater that is left running for 10 hours.

Solution: Multiply the Watts by the time the device is operating to find the number of Watt-hours that are used:

1,500 x 10 = 15,000 Wh

We are charged by kilowatt-hour for our energy use. To convert watt-hours to kilowatt-hours, divide by 1,000. (There are 1,000 watts in a kilowatt)

15,000 ÷ 1,000 = **15 kWh**

Example 2: How many kWh per year are used by a refrigerator that uses 14 kWh in a 47 hours

14 ÷ 47 x 24 x 365 = **2,609.36** or **2,609 kWh per year**

Problem 1: Compare the kWh used by a 13-Watt CFL (compact fluorescent light) with the kWh used by a 60-Watt incandescent bulb if they are used for 100 hours each month.

Problem 2: How much money can be saved each month by changing the incandescent to the CFL (from the question above), if energy costs $0.18 per kWh?

Problem 3: How many kWh are used by a set of 6 recessed lights (65 Watts each) if they are left on for security during a 1-week vacation (180 hours)?

Problem 4: A refrigerator uses 19 kWh in 40 hours, how many kWh does it use per year?

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2. Simple payback: (simplified version of Return on Investment):

Find the number of years it would take for the measure to pay for itself. Take the total cost of the measure divided by savings each year due to that measure.

Example 1: What is the simple payback for installing a high efficiency furnace for $5,000 if the annual savings from this furnace are $160?

Solution: To find the number of years it takes for the measure to pay for itself, divide the total cost by the annual savings:

$5,000 ÷ $160 = **31.25 years**

Example 2: What is the simple payback for replacing an old refrigerator with an Energy Star model costing $1,400 if the monthly savings are projected to be $11?
Solution: First, convert the monthly savings to annual savings by multiplying by 12:

$11 x 12 = **$132 per year**

Then divide the total cost by the annual savings:

$1,400 ÷ $132 = **10.6 years**

Problem 1: What is the simple payback for installing a solar PV system for $18,000 if the annual savings is projected to be $850?

Problem 2: What is the simple payback for replacing old windows with new double paned windows for$25,000 if the annual savings on the heating bill is predicted to be $500?

Problem 3: What is the simple payback for replacing incandescent lighting with LEDs for the entire house at a cost of $1,300, if the monthly savings is predicted to be $20?

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3. Savings to investment ratio (SIR) (a form of "Return on Investment"):

Multiply annual savings by the number of years the measure is expected to last; divide the result by the investment made in the measure (cost).

Example 1: What is the Savings to Investment Ratio for installing a high efficiency furnace for $1,000 if the annual savings from this furnace is $60 and the furnace is expected to last 15 years?

Solution: There are two pieces of information you need: 1) The Total Savings, and 2) The Total Investment. In this case, the Total Investment is $1,000 (we don't have any other information, such as the cost of upkeep). How much is the Total Savings? That depends on how long the furnace lasts. We save $60 per year, but for how long? We are told that the furnace will last for 15 years, so we need to multiply the savings by the time:

15 years x $60 = $900 Total Savings

The Savings to Investment ratio must be written with Savings first, i.e., on top of the fraction.

$900 ÷ $1,000 = **0.90**

If the result is 1.0, the measure pays for itself, the higher the better.

Example 2: What is the Savings to Investment Ratio for replacing an old refrigerator with an Energy Star model costing $1,400 if the monthly savings are projected to be $11 and the refrigerator is expected to last for 20 years?

Solution: Determine: 1) The Total Savings, and 2) The Total Investment. In this case the Total Investment is $1,400

How much is the Total Savings? We save $11 per month, or ($11 x 12) per year. That is a total of $132 per year, but for how long? We are told that the refrigerator will last for 20 years, so we need to multiply the savings by the time:

$132 x 20 years = $ 2,640 Total Savings So the Savings to Investment ratio is:

$2,640 ÷ $1,400 = **1.89** (it will pay for itself and then some)

Problem 1: What is the Savings to Investment ratio for installing a solar PV system for $18,000 if the annual savings is projected to be $850 and the PV system is expected to last for 20 years?

Problem 2: What is the Savings to Investment ratio for replacing old windows with new double pane windows for $25,000 if the annual savings on the heating bill is predicted to be $500 and the windows last for 30 years?

Problem 3: What is the Savings to Investment ratio for replacing incandescent lighting with LEDs for the entire house at a cost of $1,300, if the monthly savings is predicted to be $20 and the LEDs last for 40 years?

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4. Baseload formula for each fuel type: average of 3 lowest months x 12:

The remainder of the annual bills constitutes the annual heating cost (usually gas) and cooling cost (electricity).

Example 1: Find the annual baseload for the following Gas Bills

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
$ Gas	100	110	65	43	27	**23**	**21**	**24**	29	26	59	106

Solution: First, find the 3 lowest bills and average them.

(23 + 21 + 24) ÷ 3 = **22.67**

Then determine the annual cost based on this average, i.e., multiply the average by 12 months:

22.67 x 12 = **$272 per year**

The formula looks like this: $\left(\frac{23 + 21 + 24}{3}\right)$ x 12 = **$272 annual gas baseload**

Example 2: Find the annual baseload for the following Electric Bills

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
$ Elec	49	41	**37**	**40**	**34**	51	94	112	114	96	40	45

Solution: Find the 3 lowest bills and put them into the formula:

$\left(\frac{37 + 40 + 34}{3}\right)$ x 12 = **$444 annual electric baseload**

Problem 1: What is the annual baseload for each utility, Gas and Electric, based on the following bills:

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
$ Gas	740	760	580	410	48	38	36	42	56	190	370	590
$ Elec	80	68	60	58	56	124	278	292	304	186	68	82

Unit IV: HEAT

1. BTU conversions:

12,000 BTUh per Ton of AC

100,000 BTUs per Therm

Example 1: How many BTUh of heat can a 5 ton Air Conditioner remove from the air?

Solution: Multiply the tons by 12,000 to find BTUh

5 x 12,000 = **60,000 BTUh**

Example 2: If an Air Conditioner is labeled as being 36,000 BTUh, how many Tons is it?

Solution: Divide the BTUh by 12,000 to find the Tons

36,000 BTUh ÷ 12,000 = **3 Tons**

Example 3: If a Heat Pump is labeled as being 54,000 BTUh, how many Tons is it?

Solution: Divide the BTUh by 12,000 to find the Tons

54,000 BTUh ÷ 12,000 = **4.5 Tons**

Example 4: If 12 million BTUs are saved in a year based on a retrofit measure, how many annual Therms are saved?

Solution: Divide BTUs by 100,000 to find the Therms

12,000,000 ÷ 100,000 = **120 Therms**

Problem 1: How many BTUh of heat can a 3.5 ton Air Conditioner remove from the air?

Problem 2: If a Heat Pump is labeled as being 18,000 BTUh, how many Tons is it?

Problem 3: If 3 million BTUs are saved in per month based on a retrofit measure, how many monthly Therms are saved?

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2. Calculate Heating Degree Days (HDD):

Subtract the average daily outside temperature from 65°F.

Example 1: If today's average temperature is 47°F, how many Heating Degree Days are accumulated?

Solution: We calculate Heating Degree Days based on a "comfort" temperature of 65°F. In other words, if the average temperature in a day is LOWER than 65°F outside, we feel cold inside and are likely to use heating. The lower the temperature, the more heating we'll use. By subtracting the average daily temperature from 65°F, we can get a feeling for how much heating will be used.

Subtract the average daily temperature from 65°F to find the Heating Degree Days:

65°F – average daily temperature = HDD:

65 - 47 = **18 HDD** accumulated today

Example 2: If today's high temp is 40°F and low temp is 20°F, how many Heating Degree Days are accumulated for today?

Solution: First, find the average temperature today.

High temperature + low temperature ÷ 2 = average daily temperature

$$(40 + 20) \div 2 = 30°F.$$

Next, subtract that average from 65°F:

65°F - 30°F = **35 HDD**

Example 3: If today's high temp is 85°F and low temp is 55°F, how many Heating Degree Days are accumulated?

Solution: First, find the average temperature today.

$$(85 + 55) \div 2 = 70°F.$$

Next, subtract that average from 65°F:

65°F - 70°F = **-5 HDD**

There is no such thing as negative Heating Degree Days, so the answer is ZERO, or 0 HDD

Problem 1: If today's average temperature is 53°F, how many Heating Degree Days are accumulated?

Problem 2: If today's high temp is 92°F and low temp is 56°F, how many Heating Degree Days are accumulated?

Problem 3: If today's high temp is 75°F and low temp is 45°F, how many Heating Degree Days are accumulated?

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3. Heat Load used to calculate equipment size (for a room, an assembly or a whole house):

$Q = U A \Delta T$

Example 1: How many BTUh are needed to heat a room if it has a total exterior surface area of 500 square feet, and the average U value of the exterior surface is 0.07? The room is in New York City, with a winter design temperature of 15°F.

Solution: The formula is $Q = U \times A \times \Delta T$

We want to find Q, which is the total heat in BTUh.

In this case, we are given a U-value of 0.07 and we are given the exterior surface area of the room of 500 square feet. So, we know two of the values, but how do we determine the value of ΔT?

ΔT is the difference between a set "Indoor Comfort" temperature of 70°F and the Design Temperature of the location of the building. The Design Temperature is the coldest realistically expected temperature that the building will have to deal with for any length of time. It is typically measured as the outdoor temperature that this location stays above for 99% of all the hours in the year, based on a 30-year average. For New York City, the winter Design Temperature is 15°F.

To find the value of ΔT, subtract the winter Design Temperature from 70°F (the "Indoor Comfort" temperature, which always stays the same).

70°F – winter design temperature = ΔT

70°F - 15°F = 55°F

Now, plug everything into the formula:

Q = 0.07 x 500 square feet x 55°F = **1,925 BTUh**

Example 2: How many BTUh are needed to heat a house if it has a total exterior surface area of 5,000 square feet and the weighted R-value of the exterior surface is R-12? The room is in San Francisco, with a winter design temperature of 38°F.

Solution: This time, we have to calculate the average U value using the "one over" rule: U = 1 ÷ 12 = 0.083 We calculate ΔT using the winter Design Temperature for San Francisco:

70°F - 38°F = 32°F

Now, plug everything into the formula:

Q = 0.083 x 5,000 square feet x 32°F = **13,280 BTUh**

Problem 1: How many BTUh are needed to heat a room in LA (Winter Design Temp = 43°F) if it has a total exterior surface area of 800 square feet, and the weighted U value of the exterior surface is 0.2?

Problem 2: How many BTUh are needed to heat a house in Fresno (Winter Design Temp = 30°F) if it has a total exterior surface area of 8,000 square feet, and the weighted R-value of the exterior surface is R-6?

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4. Heat loss for the season used to calculate money/energy savings opportunities:

Q = U A x HDD x 24 for that location for the year.

Example 1: (Before Retrofit) What is the heat loss through the attic if it is insulated to R-12 in a one story 2,000 square foot house in New York City (5,100 annual HDD)?

Solution: We use the formula below to find Q (total heat loss in BTU):

Q = U x A x HDD x 24

We are given the R-value, so we need to calculate the U-value using the "one over" rule.

U = 1 ÷ 12 = 0.0833

We know the Surface Area where heat is being lost through the attic (same as the floor area)

A = 2,000 square feet

Once we find the HDD (heating degree days) for the location of the building, we convert it from days to hours by multiplying by 24.

HDD x 24 = 5,100 x 24

So, the formula is:

Q = 0.0833 x 2,000 x 5,100 x 24 = **20,391,840 BTUs**

Example 2: (After Retrofit) What would the annual savings be if we increased the attic insulation from R-12 (above) to R-38 in this one-story 2,000 square foot house in New York City (5,100 annual HDD)?

Solution: In this case we need to find the difference between the heat loss BEFORE and AFTER. After we add insulation, we have an attic at R-38, so we need to calculate the U-value.

U = 1 ÷ 38 = 0.0263

So, the AFTER formula: Q = U x A x HDD x 24 is the same as above, except the U value has changed.

Q = 0.0263 x 2,000 x 5,100 x 24 = **6,438,240 BTUs**

The difference, i.e. SAVINGS, between the two is 20,391,840 - 6,438,240 = 13,953,600 BTUs This is equivalent to 139.5 Therms, or approximately **$140 per year** (if the cost is $1 per Therm, and the furnace is 100% efficiency)

Problem 1: What is heat loss through the attic if it is insulated to R-30 in a one-story 2,000 square foot house in Stockton (2,600 annual HDD)?

Problem 2: What is heat loss through the attic if it is insulated to R-60 in a one-story 2,000 square foot house in Anchorage (9,400 annual HDD)?

Unit V: Ventilation

1. Ventilation ASHRAE 62.2 (2013, 2016, 2019):

CFM = (0.03 x conditioned floor area) + (7.5 x (number of bedrooms + 1))

Example 1: How many CFM is needed for a home with 1,250 sq. ft. and 2 bedrooms.

Solution: (0.03 x 1,250) + (7.5 x (2 + 1)) = 60 CFM

Example 2: A home with 4 bedrooms and a conditioned area is 3,245 sq. ft. How many CFM is needed for the whole house?

Solution: (0.03 x 3,245) + (7.5 x (4 + 1)) = 134.85 or 135 CFM

Problem 1: A 1,200 square foot apartment has 2 bathrooms and 2 bedrooms. How many CFMs are needed to meet ASHRAE 62.2 2013?

Problem 2: A house has 5 bedrooms and is 4,247 sq. ft. What should the whole house ventilation be?

Unit VI: Links

1. Area and Volume:

http://www.mathgoodies.com/lessons/vol1/practice_unit1.html

http://www.aaamath.com/geo79_x9.htm

http://www.aaamath.com/geo79_x7.htm

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2. Triangles:

http://www.aaamath.com/geo78_x6.htm

http://www.aaamath.com/geo79_x1.htm