POLITECNICO
MILANO 1863

**Name:** Amir Saman Gholami Shamami
**Student Number:** 10701028
**Submission Date:** 29/10/2019
**Assignment #:** $4^{th}$ Week

**Exercise : Determine the overall unit thermal resistance (the *R*-value) and the overall heat transfer coefficient (the *U*-factor) of a wood frame wall that is built around 38-mm 90-mm wood studs with a center-to-center distance of 400 mm. The 90-mm-wide cavity between the studs is filled with glass urethane rigid foam insulation. The inside is finished with 13-mm gypsum wallboard and the outside with 13 mm plywood and 13-mm 200-mm wood bevel lapped siding. The insulated cavity constitutes 75 percent of the heat transmission area while the studs, plates, and sills constitute 21 percent. The headers constitute 4 percent of the area, and they can be treated as studs.**

- First thing we have to do is to calculate $R_{total}$ $(R')$ , while imagining every material within the cavity as a single layer.

- Second thing is to find the Unit Thermal Resistance from the corresponding table and also to proportionally calculate the ones which exceeds the standard unit dimensions.

| | Wood Studs | Urethane Rigid Ins. |
|---|---|---|
| Outside Air | 0.03 | 0.03 |
| Wood Bevel | 0.14 | 0.14 |
| Plywood (13 mm) | 0.11 | 0.11 |
| Urethane Rigid Foam | - | $0.98\times(\frac{90}{25})= 3.528$ |
| Wood Studs | 0.63 | - |
| Gypsum Board | 0.079 | 0.079 |
| Inside Surface | 0.12 | 0.12 |

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$$R'_{wood} = 0.03 + 0.14 + 0.11 + 0.63 + 0.079 + 0.12 = \boxed{1.109\ m^2\frac{C°}{\mathrm{W}}}$$

$$R'_{urethane} = 0.03 + 0.14 + 0.11 + 3.528 + 0.079 + 0.12 = \boxed{4.007\ m^2\frac{C°}{\mathrm{W}}}$$

- In order to calculate the overall unit thermal resistance, we need to do as following:

- $$\frac{1}{R_{total}} = \frac{1}{R_{wood}} + \frac{1}{R_{ins}}$$
- $$R'_{total} = \frac{R_{total}}{\mathrm{A}}$$

$$\Rightarrow \frac{1}{\frac{R'_{total}}{A_{total}}} = \frac{1}{\frac{R'_{wood}}{A_{wood}}} + \frac{1}{\frac{R'_{ins}}{A_{ins}}}$$

$$\Rightarrow \frac{A_{total}}{R'_{total}} = \frac{A_{wood}}{R'_{wood}} + \frac{A_{ins}}{R'_{ins}}$$

- As we know from previous presentations: $R' = \frac{1}{\mathrm{U}}$

$$\Rightarrow U_{total} \times A_{total} = (U_{wood} \times A_{wood}) + (U_{ins} \times A_{ins})$$

$$\Rightarrow U_{total} = \left(U_{wood} \times \frac{A_{wood}}{A_{total}}\right) + \left(U_{ins} \times \frac{A_{ins}}{A_{total}}\right)$$

$$\Rightarrow U_{total} = (U_{wood} \times 0.25) + (U_{ins} \times 0.75)$$

- Based on previous calculations and the relationship of $R'$ and $U$ :

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- $$U_{wood} = \frac{1}{R_{wood}} = \frac{1}{1.109} \approx 0.901$$
- $$U_{wood} = \frac{1}{R_{ins}} = \frac{1}{4.007} \approx 0.250$$

$$\Rightarrow U_{total} = (0.901 \times 0.25) + (0.250 \times 0.75) \approx \boxed{0.413 \frac{W}{C°m2}}$$

- Now we can calculate the following results

- $$R'_{total} = \frac{1}{U_{total}} = \frac{1}{0.413} \approx \boxed{2.42 \frac{C°m2}{W}}$$
- $$Q_{total} = U_{total} \times A_{total} \times \Delta T$$

$$\Rightarrow Q_{total} = 0.413 \times 100 \times 24 \approx \boxed{991\ \mathrm{W}}$$

**Summary**

the third method of heat transfer is called radiation. In this method, the heat transfer does not depend on any medium substance and it happens through empty space. If we imagine a classroom filled with people and appliances, every single object or person emits certain amount of energy through radiation. The energy from the sun is a great example of this phenomenon.

Heat transfer through radiation happens in from of electromagnetic waves. Electromagnetic waves are a form of energy waves that have both electric and magnetic fields.

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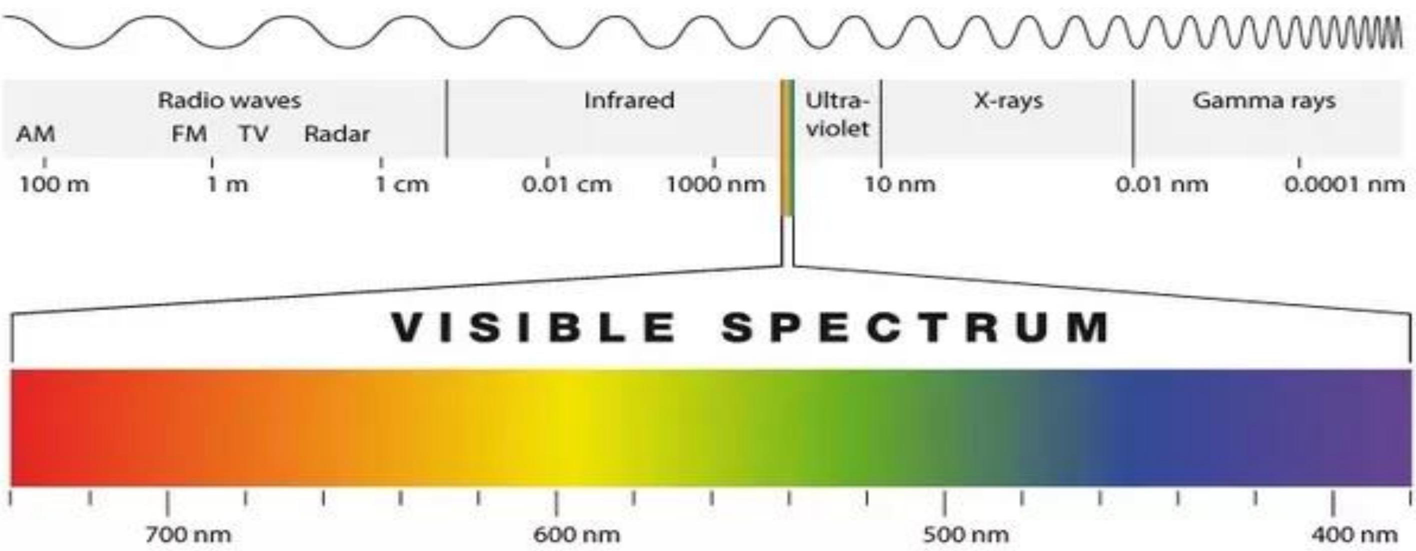



As we can see in the picture, electromagnetic waves can emit energy in variety of ranges with different wavelengths and frequencies. Temperature is a measure of strength of these activities. The rate of thermal radiation emission increases with increasing temperature. Light is the visible range of electromagnetic spectrum and a body which emits radiation in this range is called a light source.

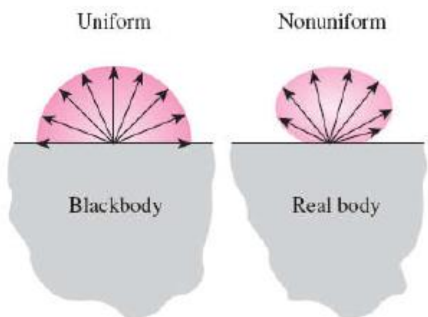
Energy emission happens in a non-uniform pattern within all surfaces. In order to do accurate measurements, scientists had to define an hypothetical object which emits the maximum possible energy in a uniform direction. Black body is an idealized body which acts as a standard model for real surfaces to be compared to. It absorbs all radiation falls on its surface and it does not reflect light and integrates power in all possible wavelenghts. The radiation energy per unit time from a black body is proportional to the forth power of the absolute temperature.

$$E_b(T) = \sigma T^4 \qquad (\mathrm{W/m^2})$$

*Blackbody emissive power*

$$\sigma = 5.670 \times 10^{-8}\ \mathrm{W/m^2 \cdot K^4}$$

*Stefan–Boltzmann constant*



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The following graph shows the variety of the black body emissive power in different temperatures with certain wavelengths:

1- The higher the absolute temperature is, the emissive power is more within lower wavelength ranges.
2- Visible light region is the range when the objects starts to change color and turn to a light source.
3- The biggest curves represents solar energy which almost half of it would be visible. Based on this fact the area of the visible range on the graph should have been almost half of the solar curve but as we see the graph demonstrates something else. The reason is that the graph below is a modified version the original logarithmic curves. In the original pattern the areas match the figures.