WEEK 4_ZHU CUILING

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

Also determine the rate of heat loss through the walls of a house whose perimeter is 50m and wall height is 2.5m in Las Vegas, Nevada, whose winter design temperature is -2°C. Take the indoor design temperature to be 22°C and assume 20% of the wall area is occupied by glazing.

	Wood	Insulation
Outside air	0.03	0.03
Wood bevel(13mm-200mm)	0.14	0.14
Plywood(13mm)	0.11	0.11
Urethane rigif foam insulation(90mm)	×	$\frac{0.98}{25} \times 90 = 3.528$
Wood studs(90mm)	0.63	×
Gypsum board(13mm)	0.079	0.079
Inside surface	0.12	0.12

$$R'_{total,wood} = 0.03 + 0.14 + 0.11 + 0.63 + 0.079 + 0.12 = 1.109 m^2 \cdot °\mathrm{C}/w$$
$$R'_{total,ins} = 0.03 + 0.14 + 0.11 + 3.528 + 0.079 + 0.12 = 4.007 m^2 \cdot °\mathrm{C}/w$$

$$\because \frac{1}{R_{total}} = \frac{1}{R_{wood}} + \frac{1}{R_{ins}}, R' = R \times A$$
$$\therefore R = \frac{R'}{A}, \frac{1}{\frac{R'_{tot}}{A_{tot}}} = \frac{1}{\frac{R'_{wood}}{A_{wood}}} + \frac{1}{\frac{R'_{ins}}{A_{ins}}} \rightarrow \frac{A_{tot}}{R'_{tot}} = \frac{A_{wood}}{R'_{wood}} + \frac{A_{ins}}{R'_{ins}}$$

Autem, $U = \frac{1}{R'}$

$$U_{tot} \times A_{tot} = U_{wood} \times A_{wood} + U_{ins} \times A_{ins} \rightarrow U_{tot} = U_{wood} \times \frac{A_{wood}}{A_{tot}} + U_{ins} \times \frac{A_{ins}}{A_{tot}}$$
$$= 0.25 \times \frac{1}{1.109} + 0.75 \times \frac{1}{4.007} \approx 0.4126 W/m^2 \cdot °\mathrm{C}$$
$$R_{value} = \frac{1}{U_{tot}} \approx \frac{1}{0.4126} \approx 2.4237 m^2 \cdot °\mathrm{C}/w$$
$$\dot{Q}_{tot} = U_{tot} \times A_{tot} \times \Delta T = 0.4126 \times 50 \times 2.5 \times (1 - 20\%) \times [22 - (-2)] = 990.24 W$$

Summary about radiation and radiative heat transfer

Definition:

- **Electromagnetic wave**

Electromagnetic waves are oscillating particle waves that are generated by the electric field and magnetic field in the same phase and perpendicular to each other. They are electromagnetic fields that propagate in the form of waves.

The process of relying on electromagnetic wave radiation to achieve heat transfer between hot and cold objects is a non-contact heat transfer that can also be carried out in a vacuum. The electromagnetic waves emitted by the object are theoretically distributed over the entire spectrum, but in the temperature range encountered in the industry, the practical significance is the thermal radiation with a wavelength between 0.38 and 1000 μm, and most of them are located in the infrared (again It is called the heat ray) in the range of 0.76 to 20 μm. The so-called infrared heating is to use the thermal radiation of this section.

- **thermal radiation**

Radiation is a phenomenon in which energy is transmitted by electromagnetic waves. The process in which radiant energy is emitted due to heat is called thermal radiation.

While scattering the emitted radiant energy, the object will continuously absorb the radiant energy emitted by other surrounding objects and convert it into heat energy. The heat transfer process between the objects that emit radiant energy and absorb radiant energy is called radiative heat transfer. It's a basic way of heat transfer.

Any object emits radiant energy while absorbing the radiant energy from surrounding objects. The difference between the energy radiated by an object and the energy absorbed is the net energy it transmits. The radiation capacity of an object (that is, the energy radiated outward from a unit surface per unit time) increases rapidly with increasing temperature.

·If the energy of the heat radiation reaching the surface of the object is completely absorbed, the object is called an absolute black body, referred to as a black body;

·If the energy of the thermal radiation reaching the surface of the object is all reflected; when the reflection is regular, the object is called a mirror;

·If it is a chaotic reflection, it is called absolute white body.

·If the energy of the heat radiation reaching the surface of the object passes through the object, the object is called a heat permeable body.

Formula

- **Electromagnetic wave**

$$\lambda = \frac{c}{v} \qquad c = \frac{c_0}{n} \qquad e = h \times v = \frac{h \times c}{v}$$

c_0: speed of light in a cacunm $c_0 = 2.9979 \times 10^8 m/s$

n: index of refraction of the medium
n=1(air and most gases) n=1.5(glass) n=1.33(water)

$h = 6.626069 \times 10^{-34} J \cdot s$ is **Planck's constant**

- **Stefan—Boltzmann's Law**

$$E_b(T) = \delta \times T^4 (W/m^2)$$

Stefan—Boltzman constant: $\delta = 5.670 \times 10^{-8} W/m^2 \cdot K^4$

- **Plank's Law**

$$E_{b\lambda}(\lambda, T) = \frac{C_1}{\lambda^5 \left[\exp\left(\frac{C_2}{\lambda \times T}\right) - 1\right]} \left(W/m^2 \cdot \mu m\right)$$

$C_1 = 2\pi h c_0^2 = 3.74177 \times 10^8 W \cdot \mu m^4/m^2$
$C_2 = h c_0/k = 1.43878 \times 10^4 \mu m \cdot K$
$k = 1.38065 \times 10^{-23} J/K$ ——Boltzmann's constant

- **Wien's Displacement Law**

$$(\lambda \times T)_{\max power} = 2897.8 \mu m \cdot K$$