QUESTION 1

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 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.

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

ANSWER

	with Wood	with Insulation
Outside Air	0.03	0.03
Wood Bevel Lapped Siding (13mm * 200mm)	0.14	0.14
Plywood (13mm)	0.11	0.11
Urethane Rigid Foam Insulation (90mm)	-	0.98*90/25=3.528
Wood Studs (90mm)	0.63	-
Gypsum board (13mm)	0.079	0.079
Inside Surface	0.12	0.12

$$R_{withwood} = 0.03 + 0.14 + 0.11 + 0.63 + 0.079 + 0.12 = 1.109\ m^2.\,°\mathrm{C}/W$$

$$R_{withinsulation} = 0.03 + 0.14 + 0.11 + 3.528 + 0.079 + 0.12 = 4.007\ m^2.\,°\mathrm{C}/W$$

$$U_{withwood} = \frac{1}{R_{withwood}} = \frac{1}{1.109} = 0.902\frac{W}{°C.m^2}$$

$$U_{withinsulation} = \frac{1}{R_{withinsulation}} = \frac{1}{4.007} = 0.250\frac{W}{°C.m^2}$$

$$U_{total} = \frac{U_{wood}A_{wood}}{A_{total_{unit}}} + \frac{U_{insulation}A_{insulation}}{A_{total_{unit}}} = 0.902 \times 0.25 + 0.250 * 0.75 = 0.413\frac{W}{°C.m^2}$$

$$A_{total} = 50 \times 2.50 \times 80\% = 100m^2$$

Rate of heat transfer through Wall:

$$\dot{Q} = A_{total} \times U_{total} \times \Delta T = 100 \times 0.413 \times \left(22 - (-2)\right) = 991.2W$$

QUESTION 2

Write a summary about radiation and radiative heat transfer

ANSWER

Definition

Radiative heat transfer is the third type of heat transfer that can occur besides conduction and convection. Thermal radiation is energy emitted by matter as electromagnetic waves, emitted by all matter with a temperature above absolute zero. The radiative heat transfer is the exchange of energy by the materials, during which heat is converted to electromagnet wave when emitted and converted back to heat when it reaches the surface.

Radiative heat transfer differs from conduction and convection in that it does not require the presence of a material medium to take place. Radiative heat transfer occurs in solids, liquids, gases. Only radiation transfer can occur through vacuum of space.

In general, radiative heat transfer is a complex phenomenon and hard to be measured exactly without the help of modern devices. Therefore, it is not easy to be generalized in to mathematic equations like convection and conduction heat transfer.

Radiation Energy

Electromagnetic waves transport energy just like other waves and they are characterized by frequency ν or wavelength λ. The energy each photon carried equals:

$$e = \frac{h\upsilon}{\lambda}$$

h is Planck's constant ($6.62607004 \times 10^{-34}$ m^2kg/s)

Light, Color and Thermal Radiation

Light is the electromagnetic radiation with the frequency/wavelength in the visible range to human eyes (between 0.40 and 0.76 μm). Different frequency/wavelength of these radiation are characterized by the color of light (from red – low frequency – long wavelength – low energy level to violet – high frequency – short wavelength – high energy level). Infrared is the invisible radiation with shorter wavelength than red light, and it relates to heat transfer in room temperature. Ultraviolet is the invisible radiation with higher wavelength than violet light.

A body that emits some radiation in the visible range is called a light source. We can see an object when it is a light source or when it reflects the light from a light source to our eyes.

Blackbody Heat Radiation

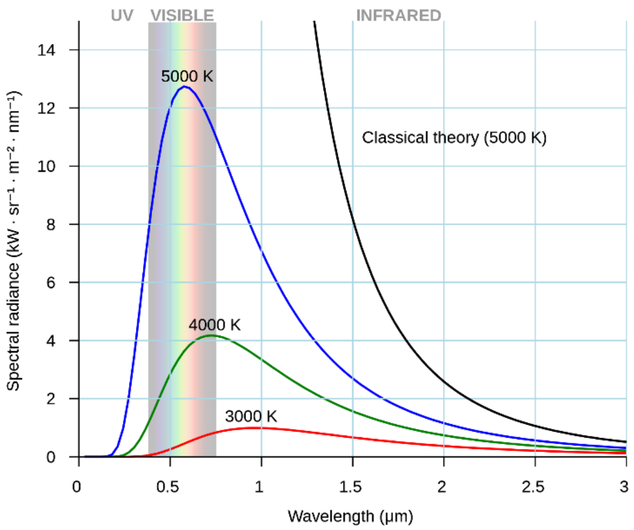
A blackbody emits the maximum amount of radiation by a surface at a given temperature. A blackbody absorbs all incident radiation, regardless of wavelength and direction. This means it does not reflect radiation and is perfect emitter and absorber of radiation. It is an idealized body to serve as a standard against which the radiative properties of real surfaces may be compared.

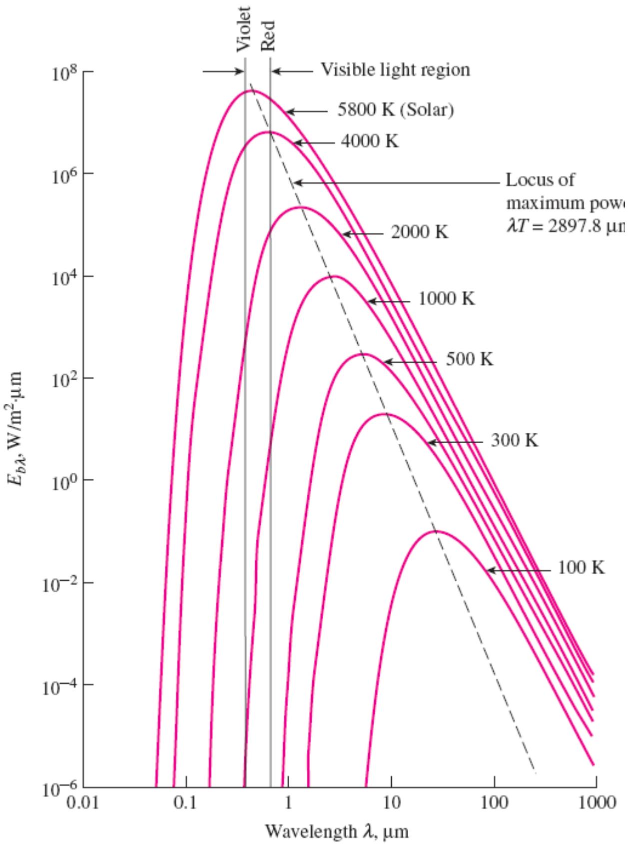
The radiation energy emitted by a blackbody is only characterized by its absolute temperature:

$$E = \sigma T^4 \quad (W/m^2)$$

σ is the Stefan–Boltzmann constant (5.67×10−8 W·m^{-2}·K^{-4})

At a specific temperature, radiation energy emitted by a blackbody can be analyzed by the graph:





The emitted radiation is a continuous function of wavelength. At any specified temperature, it increases with wavelength, reaches a peak, and then decreases with increasing wavelength.

At any wavelength, the amount of emitted radiation increases with increasing temperature.

As temperature increases, the curves shift to the left to the shorter wavelength region. Consequently, a larger fraction of the radiation is emitted at shorter wavelengths at higher temperatures.