Q- A student is trying to decide what to wear. His bedroom is at 20.0 degrees Celsius. His skin temperature is 35.0 degrees Celsius. The area of his exposed skin is 1.50 m^2. People all over the world have skin that is dark in the infrared, with emissivity about 0.900. Find the net energy loss from his body by radiation in 10.0 min.

Reading:

Prevost law for heat exchange says that all bodies at all temperatures radiate heat. If the temperature of the body is more than its surrounding then the energy radiated is more than the rate at which energy absorbed and visa-versa. If the temperature of the body and surrounding is equal then the two rates are equal and the temperature remains constant.

The rate of thermal radiation from a black body is given by Stefan's law according to which the rate of thermal radiation is per unit area per unit time from a black body is directly proportional to the fourth power of its absolute temperature. Hence according to the law

$$\frac{1}{A}\frac{dQ}{dt} \propto T^4$$

Or $$\frac{1}{A}\frac{dQ}{dt} = \sigma * T^4$$

Where σ is the proportionality constant called Stefan's constant = 5.67*10^{-8} W/(m^2T^4).

As the perfect black body surface is only an ideal for any other surface the quantity of radiation will be less and hence we introduce a quantity called emissivity (denoted by e) of the surface depending on the nature of the surface and it is the ratio of the energy radiated by the surface and blackbody surface in same situations. Hence the law can be written as

$$\frac{dQ}{dt} = Ae\sigma T^4$$

Or if the conditions remain constant we can write the rate of heat radiated as

$$\frac{\Delta Q_e}{\Delta t} = Ae\sigma T^4$$

Now if the surrounding is at temperature T_0 then it will also radiate energy and the heat absorbed by the surface will be given by

$$\frac{\Delta Q_a}{\Delta t} = Ae\sigma T_0^4$$

Hence the net heat loss by the surface due to radiations is given by

$$\frac{\Delta Q}{\Delta t} = Ae\sigma\left(T^4 - T_0^4\right) \qquad \text{-------------------- (1)}$$

Now from the question we have T = 20.0 + 273 = 293 K; T_0 = 35.0 + 273 = 308 K

A = 1.50 m^2; e = 0.900 and Δt = 10.0 min.

Substituting in equation 1 we have the rate of energy loss as

$$\frac{\Delta Q}{10 * 60} = 1.50 * 0.900 * 5.67 * 10^{-8}\left(308^4 - 293^4\right)$$

Or $\Delta Q = 124.7 * 600 = 74820$ W = 74.82 KW