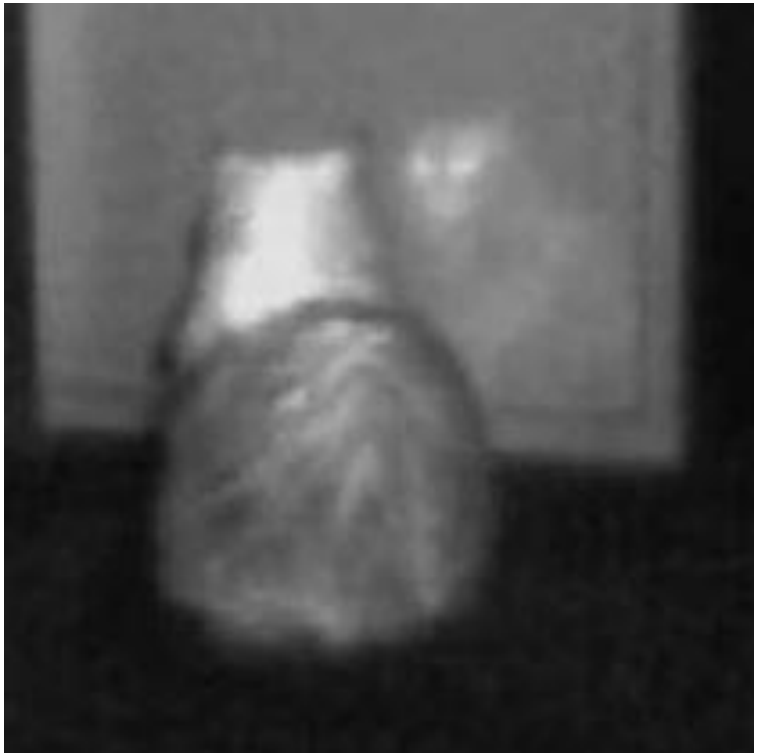
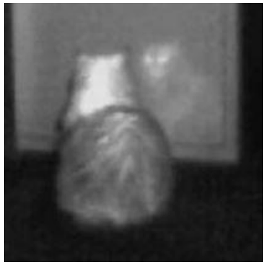
Energy Use at Home

Thermal Radiation



Lecture Notes

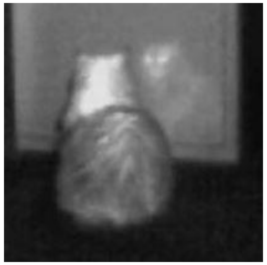


Question

All bodies emit radiation. So why don't we all shine in the dark?

Big Ideas

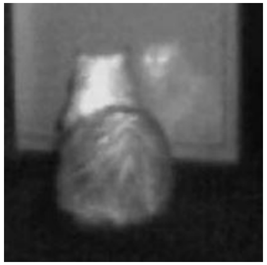
Thermal Radiation



- Thermal radiation is emitted by all bodies warmer than absolute zero
- Visible light is emitted by bodies hotter than 800^{o}C
- Bodies at room temperature emit mainly in infrared
- Very cold objects like for example liquid helium emit mainly in microwave

Radiation

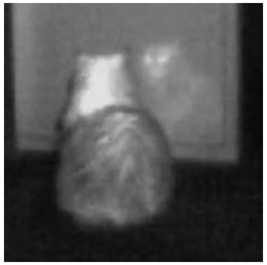
Thermal Radiation

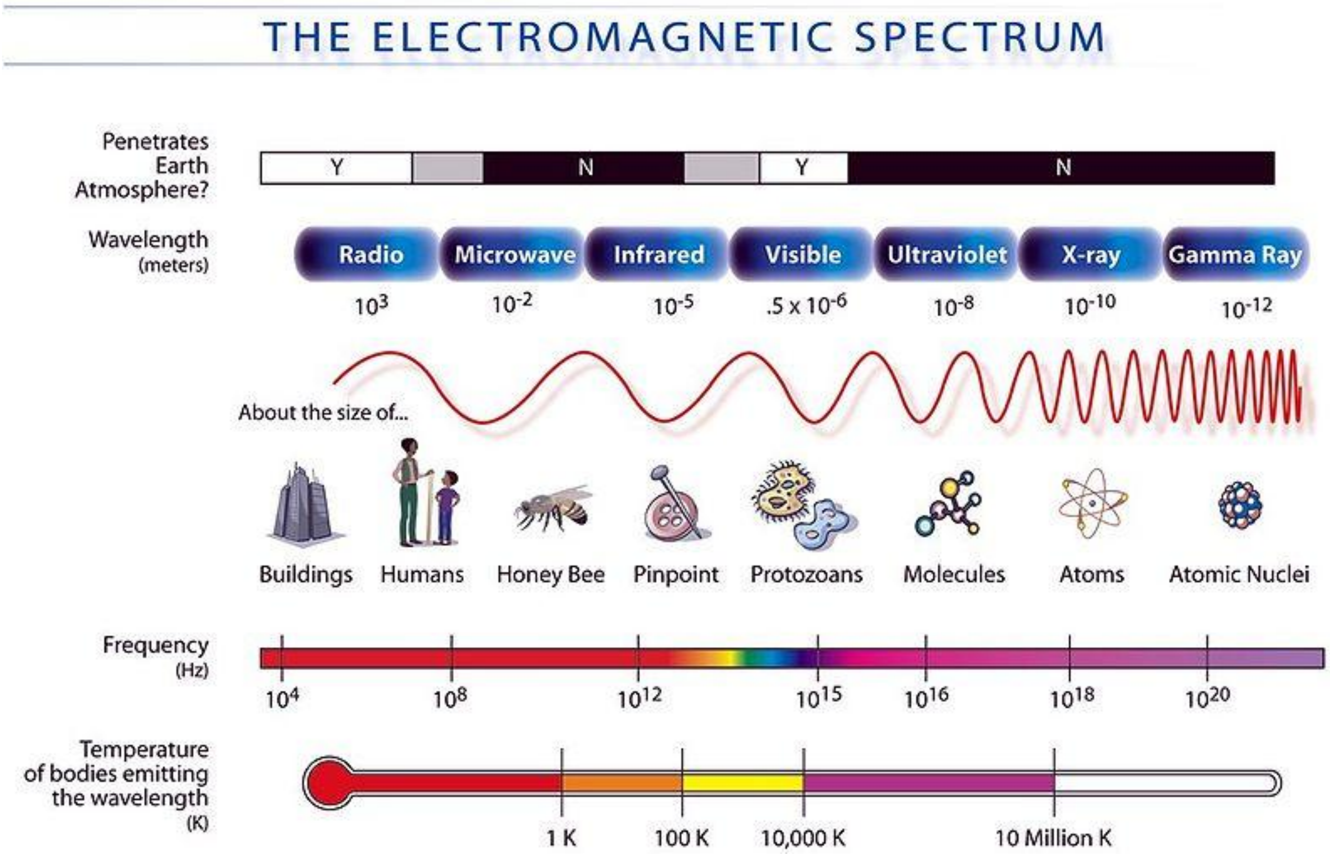


- ALL bodies warmer than absolute zero (-273^{o}C) emit radiation.
- An average human emits ~300 W of thermal radiation.
- The wavelength and power emitted by a body depends on the temperature.
- If T> 800^{o}C, the body emits visible light
- At lower temperature, bodies emit infrared
- Very cold bodies like liquid helium (-269^{o}C) emit microwaves.

Electromagnetic Spectrum

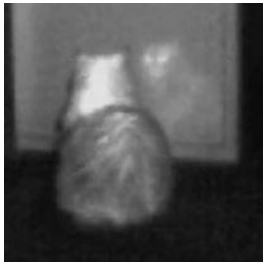
Thermal Radiation





Wavelength

Thermal Radiation



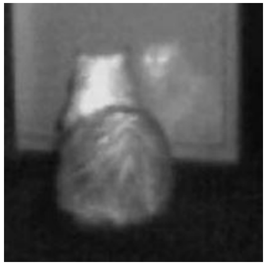
- The relationship between the temperature and the wavelength for which maximum power is emitted is:

$$\lambda_m = \frac{2.90 \text{ x } 10^{-3} \text{ m} \cdot \text{K}}{T}$$

- The higher the temperature, the lower the wavelength of the emitted thermal radiation

Seeing Radiation

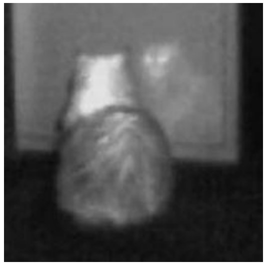
Thermal Radiation



- The temperature of the sun is 5778 K
- We calculate that the wavelength at maximum power is 500 nm (in the middle of visible spectrum)
- At the human body temperature (37^{o}C) the maximum is at about 10 μm (infrared)
- Only some snakes, bats and insects can see this radiation, we have to use a special infrared camera.

Intensity

Thermal Radiation



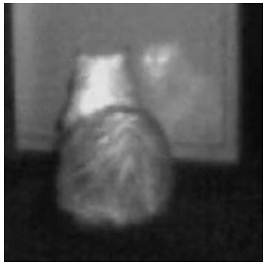
- The total emitted intensity of radiation (average power emitted per unit area of radiating body) is given by:

$$I = \varepsilon \sigma T^4$$

where *T* is temperature in degrees Kelvin, σ is the Stefan- Boltzmann constant ($\sigma = 5.67 \times 10^{-8}$ W/m^{2}K^4) and ε is emissivity.

Emissivity

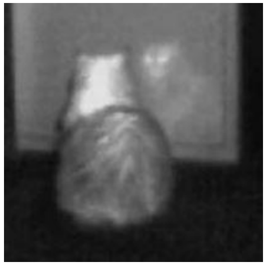
Thermal Radiation



- Emissivity is a material constant strongly dependent on the wavelength
- Higher emissivity - the material will emit or absorb more radiation at this wavelength
- Some materials have high emissivity in visible and low in infrared and vice versa
- Shiny metallic surfaces have low emissivity both in visible and infrared
- The human skin has emissivity of 0.98 in infrared, Sun has emissivity very close to 1

Emissivity - Housing

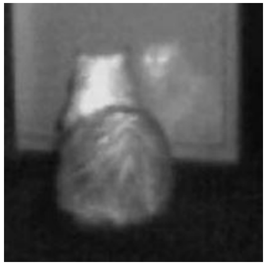
Thermal Radiation



- An ideal winter paint for the house would have high emissivity in visible (most energy from the sun comes in visible) and low emissivity in infrared (the house emits infrared).
- For the summer, we would like to have low emissivity in the visible and high in infrared to save on air conditioning.
- Unfortunately we do not have commercial paints like this we would be reluctant to repaint the house twice a year.

Radiation - Person

Thermal Radiation



- Any object emitting thermal radiation is also absorbing radiation from the surrounding.
- A person, assuming a surface area of A=1.5 m^2, ε=0.98 and skin temperature T = 33^{o}C (306 K), radiates:

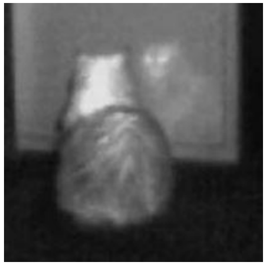
$$P_E = A\varepsilon\sigma T^4$$

$$= (1.5\text{m}^2)(0.98)(5.67 \text{ x } 10^{-8}\,\text{W/m}^2\text{K}^4)(306\text{K})$$

$$= 730 \text{ W}$$

Radiation - Person

Thermal Radiation



- When this person sits in a room at 20ºC he/she absorbs:

$$P_E = A\varepsilon\sigma T^4$$

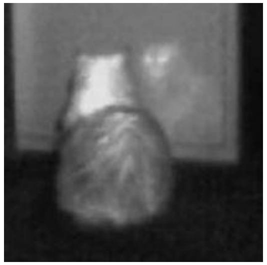
$$= (1.5\,\mathrm{m}^2)(0.98)(5.67 \times 10^{-8}\,\mathrm{W/m^2K^4})(293\,\mathrm{K})$$

$$= 615\,\mathrm{W}$$

- The net loss of energy is about 115 W.

Radiation - Person

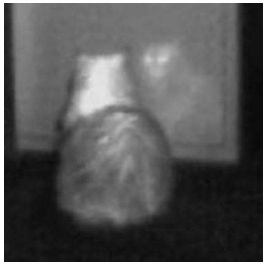
Thermal Radiation

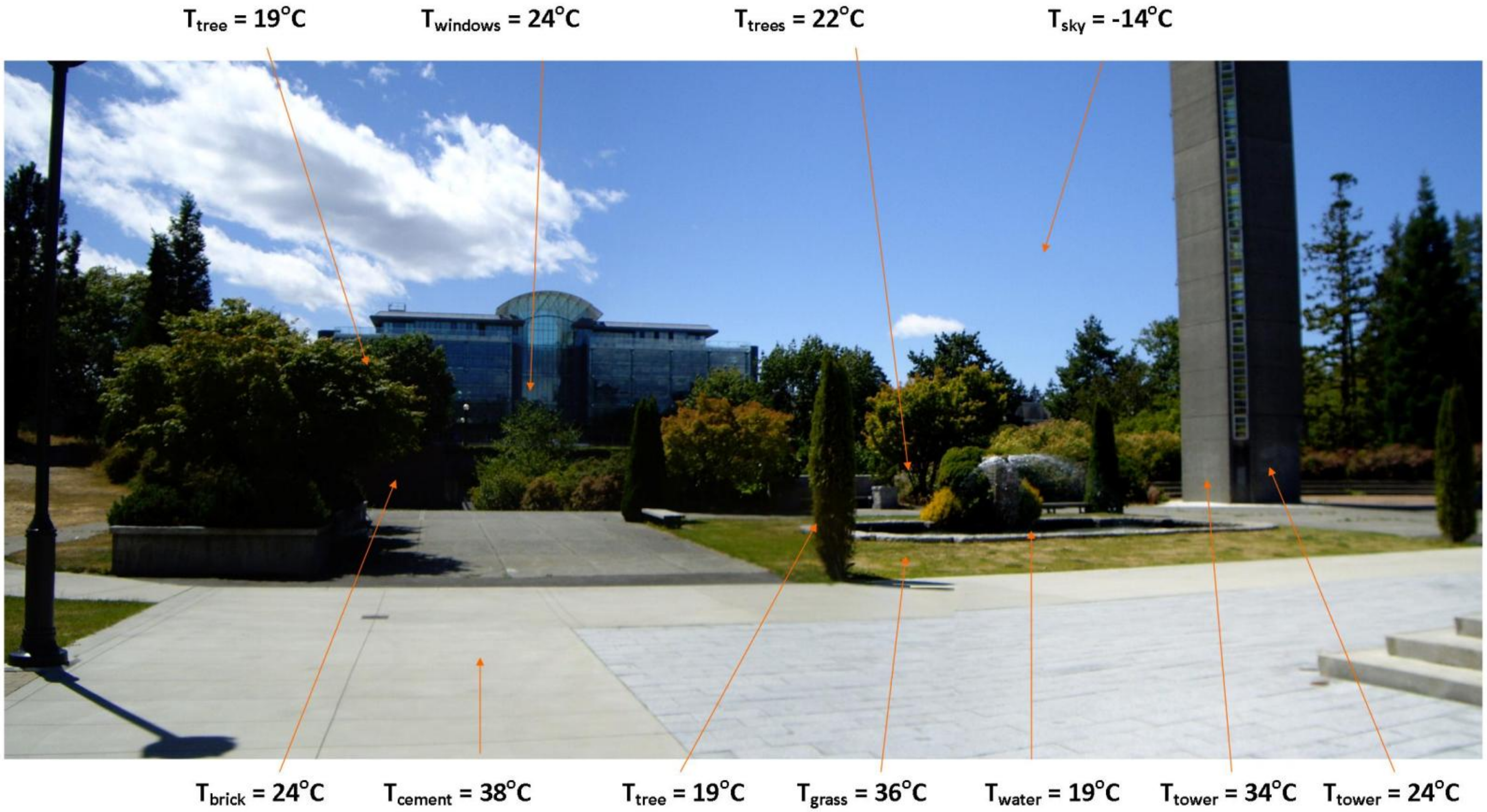


- This is ignoring the effect on clothes but the order of magnitude is consistent with our energy input from food.
- In reality a dressed person loooses about 50% of this heat to radiation and the rest to convection, evaporation and heat exchange due to breathing

Visible Light

Thermal Radiation

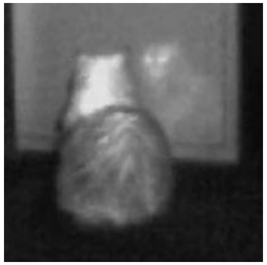


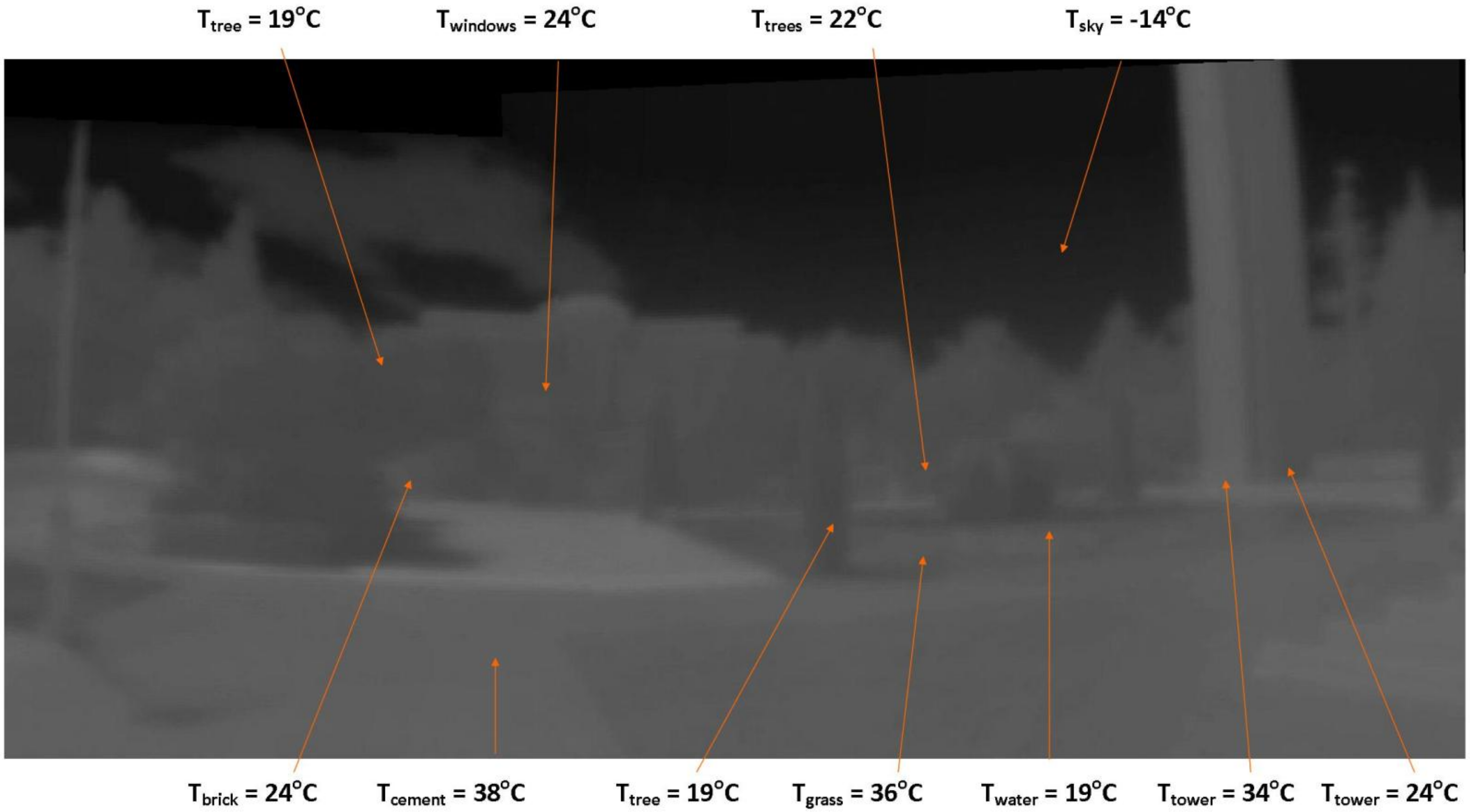


Different amounts of heat are radiated from different objects in the same environment. This was taken on a 24°C day in July.

Infrared

Thermal Radiation

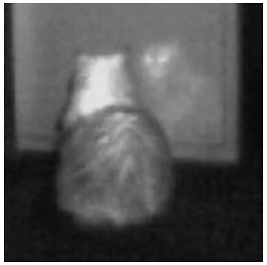




An identical picture taken with an infrared camera. Objects emitting more radiation appear light, those emitting less appear dark.

Radiation is Relative

Thermal Radiation



Top: On a June day (temperature in the high teens) the people are much hotter than the environment. Bottom: On a July day (temperature in the mid 20s), the surface temperature of the person’s clothing is ~29^{o}C but the surface temperature of the concrete is 38^{o}C.