**Solved Example 2:** The tungsten filament of an electric lamp has a length of 0.25 m and a diameter 6 × 10–5 m. The power rating of the lamp is 100 W. If the emissivity of the filament is 0.8, estimate the steady temperature of the filament. Stefan’s constant = 5.67 × 10–8 W m–2 K–4.

**Solution:** Area of the filament = 2p × (radius) × (length)

A = 2p × (3 × 10–5) × 0.25   = 4.71 × 10–5 m2

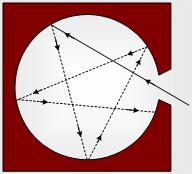
Now Q = σεT4, where Q is the energy radiated per second per unit area at absolute temperature T. Therefore, the energy radiated per second (or power radiated) from the filament of area A is, P = εσAT4

When the temperature is steady, power radiated from filament = power received = 100 W

∴ AεσT4 = 100 W

Now A = 4.71 × 10–5 m2, ε = 0.8 and σ = 5.67 × 10–8 W m–2 K–4

Substituting these values, we have, T = (100/4.71 × 10–5 × 0.8 × 5.67 × 10–8)1/4 = 2616 K



**Cavity approximating an ideal black body**

Radiation entering the cavity has little chance of leaving before it is completely absorbed. (e ≈ 1)

Materials like black velvet or lamp black come close to being ideal black bodies, but the best practical realization of an ideal black body is a small hole leading into a cavity, as this absorbs 98% of the radiation incident on them.

**(ii) Absorptive power ‘a’:** “It is defined as the ratio of the radiant energy absorbed by it in a given time to the total radiant energy incident on it in the same interval of time.”

            a = energy absorbed/energy incident

As a perfectly black body absorbs all radiations incident on it, the absorptive power of a perfectly black body is maximum and unity.

Stefan-Boltzmann Equation: Relates Temperature and Power Flux

F = ∙∙T4

F = Radiant Flux (irradiance) in W/m2

= emissivity constant (unitless) (≈1 for perfect blackbody radiator, such as a star)

= Stefan-Boltzmann constant = 5.67 × 10-8 W/(m2K4)

T = Temperature in Kelvin (note: K = °C + 273.15°)

Example: If the area of the tungsten filament in a 100 W incandescent light bulb is 0.26 cm2, and the emissivity is 0.36, what is the temperature of the filament?

Solution:

First, let's solve the equation for T, since that is what we are finding:

F = ∙∙T4

F/∙) = T4

(F/∙))1/4 = T

Next, let's get F. We know the power is 100 W, but we need it in terms of W/m2. The area is 0.26 cm2,

which is 2.6 × 10-5 m2. So F is equal to 100 W/(2.6 × 10-5 m2) = 3.846 × 106 W/m2

Now we plug everything in:

(F/∙))1/4 = T

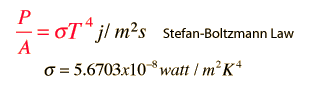
(3.846 × 106 W/m2)/(0.36\*5.67 × 10-8 W/(m2K4))1/4

(check the units!) W and m2 both cancel, leaving (K4)1/4 = K Good!

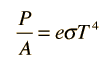
T = 3705 K = 3432° C

**Stefan-Boltzmann Law**

The energy radiated by a [blackbody radiator](http://hyperphysics.phy-astr.gsu.edu/hbase/mod6.html#c1) per second per unit area is proportional to the fourth power of the [absolute temperature](http://hyperphysics.phy-astr.gsu.edu/hbase/thermo/temper.html#c3) and is given by



For hot objects other than ideal radiators, the law is expressed in the form:



where e is the emissivity of the object (e = 1 for ideal radiator). If the hot object is radiating energy to its cooler surroundings at temperature Tc, the net [radiation loss](http://hyperphysics.phy-astr.gsu.edu/hbase/thermo/stefan.html#c2)rate takes the form

http://hyperphysics.phy-astr.gsu.edu/hbase/thermo/imgheat/stef3.gif