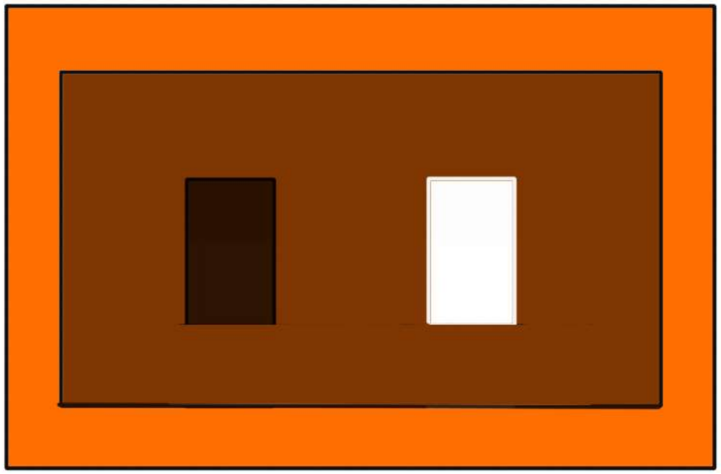


A white object and a black object both sit in an oven. The oven and the objects are in equilibrium at 1500 degrees Celcius. We can say that the **net** heat current from radiation, ($H_{absorbed}$ - $H_{emitted}$) is

A) Larger for the white object
B) Larger for the black object
C) The same for both objects and greater than zero.
D) The same for both objects and equal to zero.
E) The same for both objects and less than zero.

Assume that there are no conduction or convection effects.

EXTRA: Which object is emitting more radiation?

How to study for the midterm:

1. Do practice problems
   - homework, tutorials, old midterms, clicker questions
   - use slides, solutions, problem solving tips as reference,
2. Do more practice problems
3. Repeat

But continue to eat, sleep, exercise

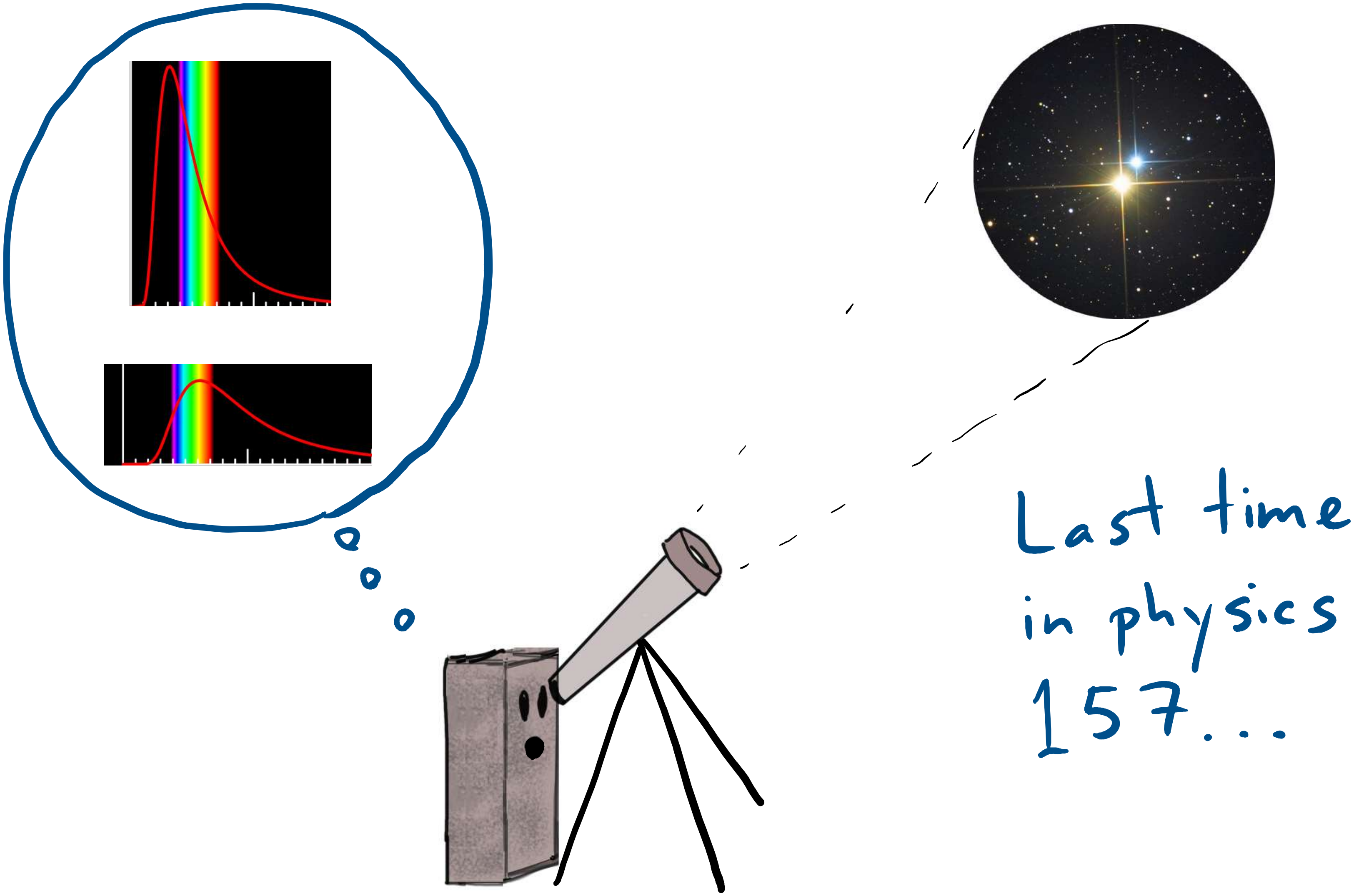
Nobel Prize 2018 with Arthur Ashkin
Gerard Mourou

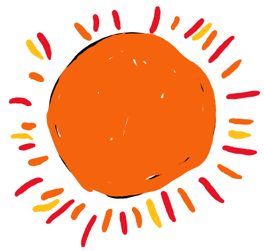
eng-phys!

Donna T. Strickland - U. Waterloo

from Guelph, Ontario

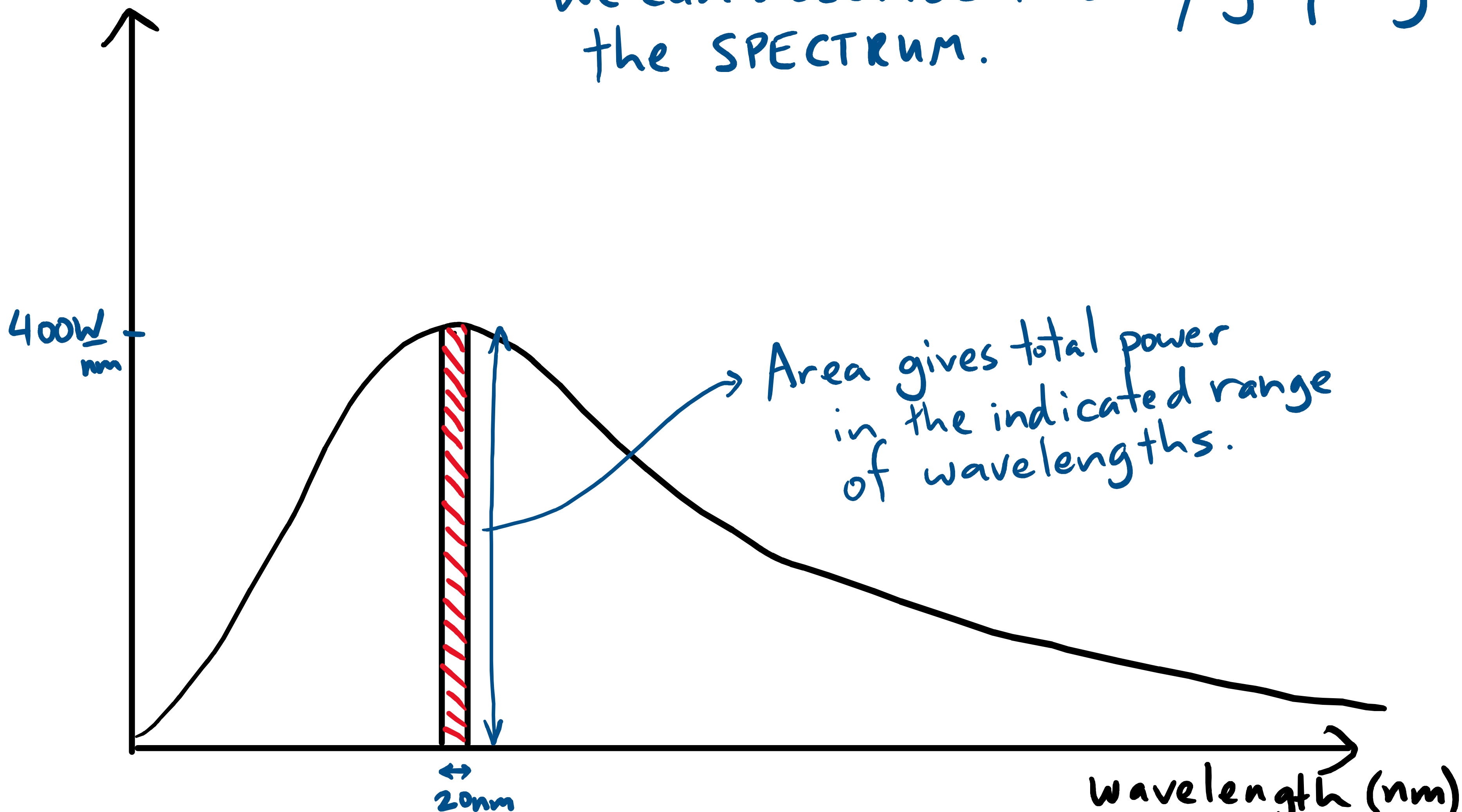
2013 OSA President Donna Strickland received her B. Eng. Degree in Physics, from McMaster University in 1981. She graduated from the University of Rochester in 1989 with a Ph.D. in Optics. Along with her Ph.D. supervisor, Dr. Gerard Mourou, Donna Strickland co-invented Chirped Pulse Amplification (CPA), which made it possible to amplify ultra-short pulses to unprecedented levels. From 1988 to 1991, Strickland was a research associate at the National Research Council of Canada. The following year, she was a physicist with the laser division of Lawrence Livermore National Laboratory. In 1992, she became a member of the technical staff of Princeton's Advanced Technology Center for Photonics and Opto-electronic Materials. Strickland joined the physics department of the University of Waterloo as an assistant professor in 1997. At Waterloo, Strickland's ultrafast laser group develops high-intensity laser systems for nonlinear optics investigations. She was promoted to Associate Professor in 2002 and since 2007 has been the Associate Chair of the Department. Strickland was selected as an Alfred P. Sloan Research Fellow in 1998. She received a Premier's Research Excellence Award in1999 and a Cottrell Scholars Award from Research Corporation in 2000 and was named a Fellow of the OSA in 2008.


Last time
in physics
157...

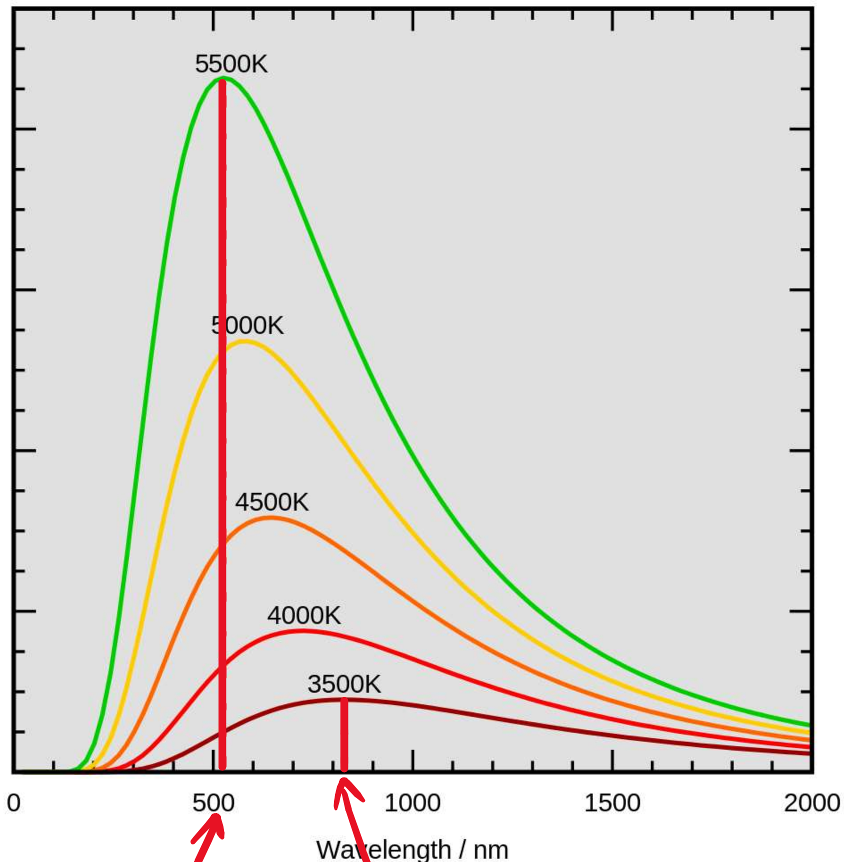


Radiation from an object comes in a mix of wavelengths.

We can describe this by graphing the SPECTRUM.



Peak wavelength is inversely proportional to T



λ_{max} for 5500K

λ_{max} for 3500K

$$\lambda_{max} = \frac{b}{T}$$

b = 2.9 K·mm

Wien displacement law

sun: peak at ≈ 500 nm → 5700 K

outer space: peak at 1 mm → 2.7 K

"COSMIC MICROWAVE BACKGROUND"

Total power is proportional to T^4

heat current

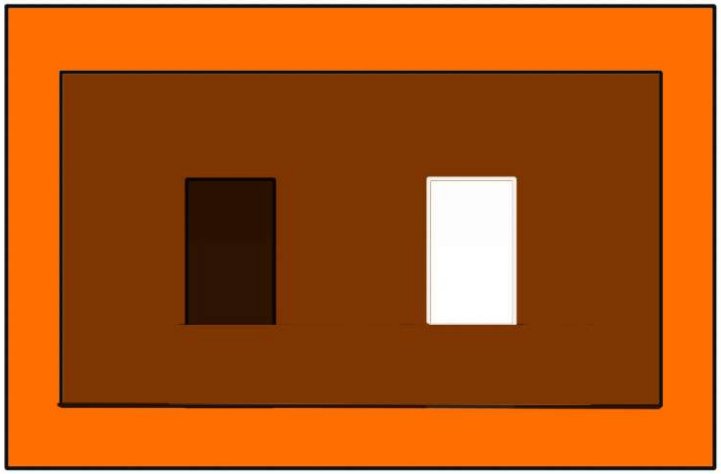
surface area

$$H = A \cdot e \cdot \sigma \cdot T^4$$

emissivity

Stefan-Boltzmann constant

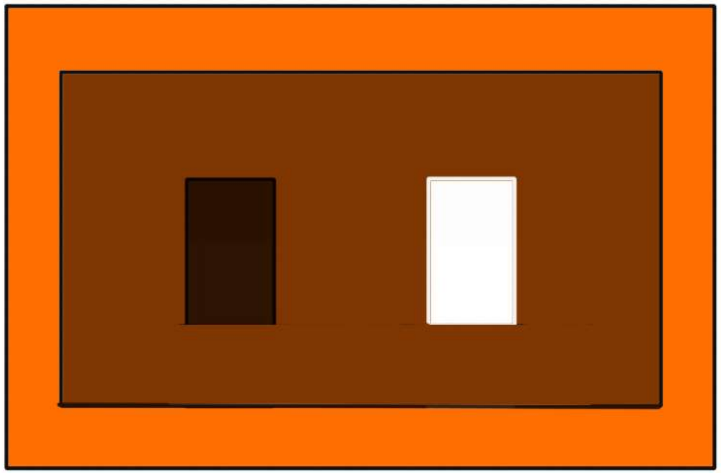
$5.67 \times 10^{8} \frac{W}{m^2 \cdot K^4}$



A white object and a black object both sit in an oven. The oven and the objects are in equilibrium at 1500 degrees Celcius. We can say that the **net** heat current from radiation, ($H_{absorbed}$ - $H_{emitted}$) is

A) Larger for the white object
B) Larger for the black object
C) The same for both objects and greater than zero.
D) The same for both objects and equal to zero.
E) The same for both objects and less than zero.

Assume that there are no conduction or convection effects.
EXTRA: Which object is emitting more radiation?



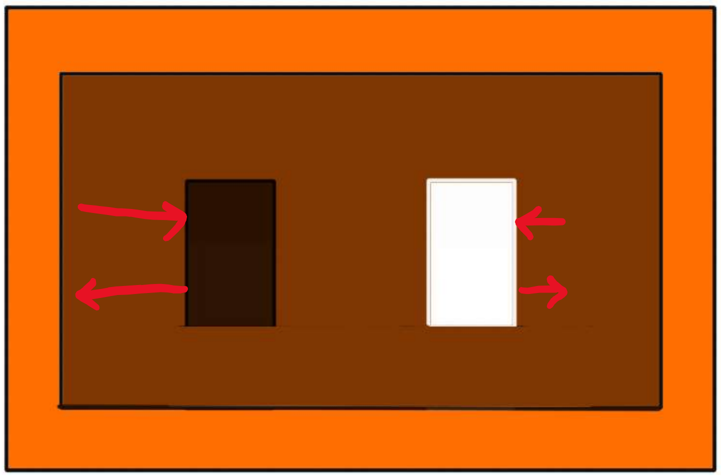
A white object and a black object both sit in an oven. The oven and the objects are in equilibrium at 1500 degrees Celcius. We can say that the **net** heat current from radiation, ($H_{absorbed}$ - $H_{emitted}$) is

Equilibrium ⇒ const. T
⇒ no net heat current

∴ $H_{absorbed} - H_{emitted} = 0$

A) Larger for the white object
B) Larger for the black object
C) The same for both objects and greater than zero.
D) The same for both objects and equal to zero.
E) The same for both objects and less than zero.

Assume that there is no air in the oven and the objects are insulated from the walls so there is no conduction or convection.



A white object and a black object both sit in an oven. The oven and the objects are in equilibrium at 1500 degrees Celcius. We can say that the **net** heat current from radiation, ($H_{absorbed}$ - $H_{emitted}$) is

$H_{emitted} = H_{absorbed}$

larger for black object

∴ black object radiates more!

EMISSIVITY:

- Perfect absorber = "blackbody"
  emits the most thermal radiation for a given temperature.

- Other objects: define

$$e = \frac{H}{H_{blackbody}}$$

depends on temperature

$e = 1$ blackbody

$e = 0$ perfect mirror

Total Power From Thermal Radiation

$$H = A \cdot e \cdot \sigma \cdot T^4$$

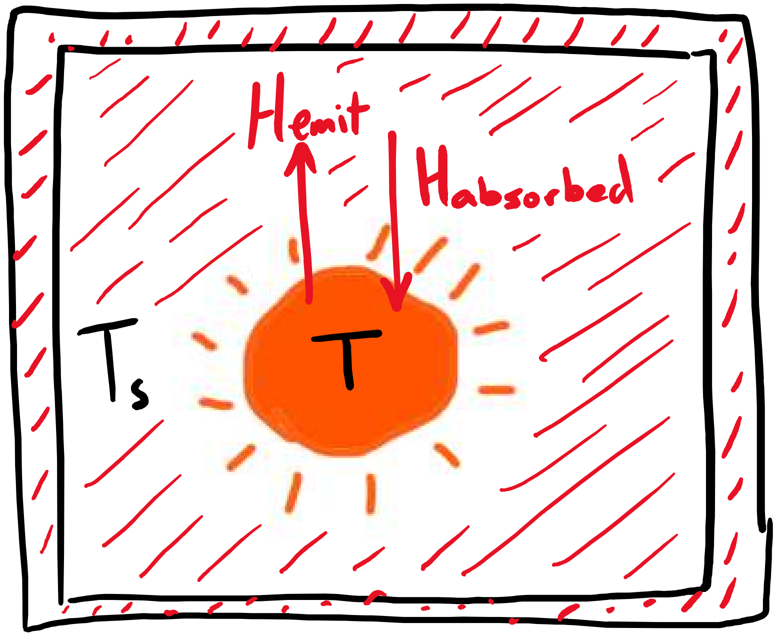
- H: heat current
- A: surface area
- e: emissivity
- σ: Stefan-Boltzmann constant, $5.67 \times 10^{8} \frac{W}{m^2 \cdot K^4}$

$e = 1$ perfect absorber (black)

$e = 0$ perfect reflector (mirror)

Net Heat Current From Thermal Radiation

(in uniform temperature environment)



surface area

$$H = A \cdot e \cdot \sigma \cdot (T^4 - T_s^4)$$

Stefan-Boltzmann constant

$5.67 \times 10^8 \frac{W}{m^2 \cdot K^4}$

temp. of surroundings

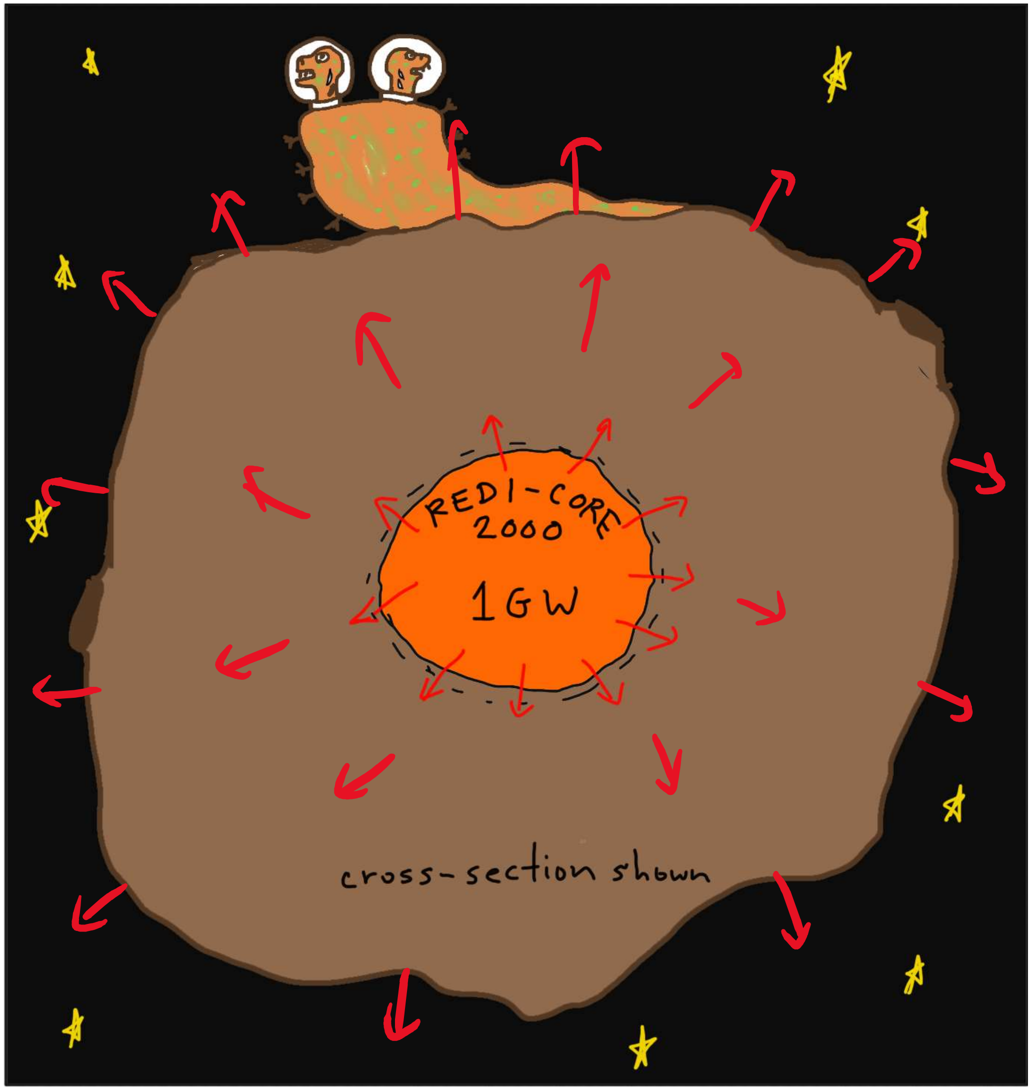
$e = 1$ perfect absorber (black)

$e = 0$ perfect reflector (mirror)

Yoltar heats their little planet (far from any stars) with a 1GW heater. If they wish to double the equilibrium *surface* temperature of their planet, they should increase the power of their heater to

A) 1.21GW
B) 2GW
C) 4GW
D) 8GW
E) 16GW

Hint: where does the energy from the heater go?



Steady state:

Power from heater = power radiated

$$P_{heater} = A \cdot \sigma \cdot e \cdot T^4$$

To double T

Need 16x P

A harder (but really interesting!) problem.

A planet with radius r = 6400km lies at a distance R = 150,000,000km from a yellow star with temperature T = 5700K and radius R_S = 695,000km. **Estimate the surface temperature of the planet.**

The planet has **albedo** (fraction of incident light reflected) A = 0.37 and emissivity *e* close to 1.

STEP 1: visualize what is going on in the problem.

- draw a picture

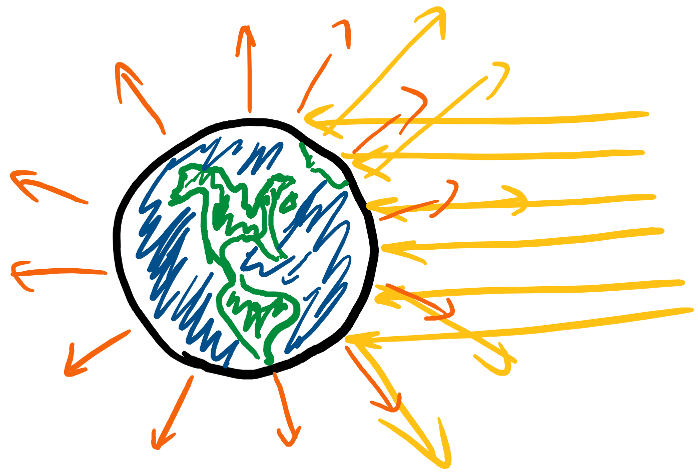
Discussion question: what physical processes are happening here that will affect the the temperature of the planet?

If the temperature is constant, what does this allow us to conclude?

Key relation for steady-state heat flow:

$$H_{in} = H_{out}$$

Our problem:



H_{in} : absorbed sunlight

H_{out} : IR radiation $= A \cdot e \cdot \sigma \cdot T^4$

What is H_{in}?