Thermal Energy Transfer & Black Body Radiation

IB PHYSICS | ENERGY PRODUCTION

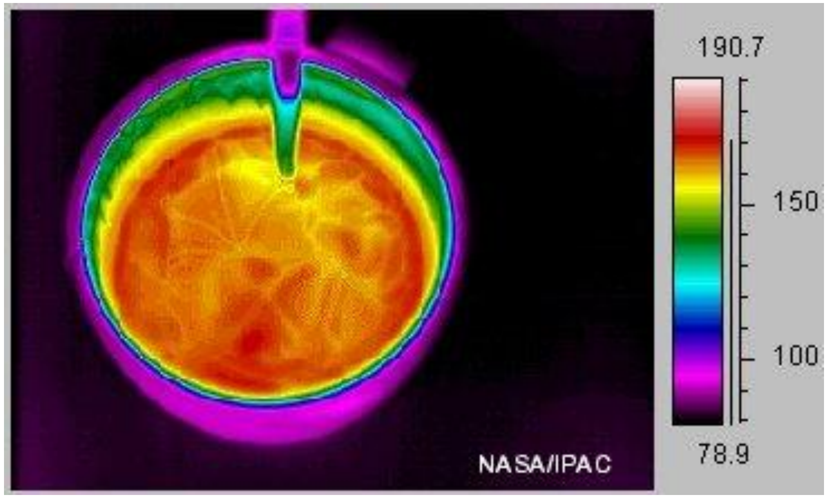
Heat Transfer

There are 3 primary ways that heat is transferred:

- Conduction
- Convection
- Radiation

Conduction

Conduction occurs between objects in direct _contact_



Conduction

Why does this frying pan have a plastic handle?

Plastic has a high specific heat and doesn't conduct heat very quickly

Convection

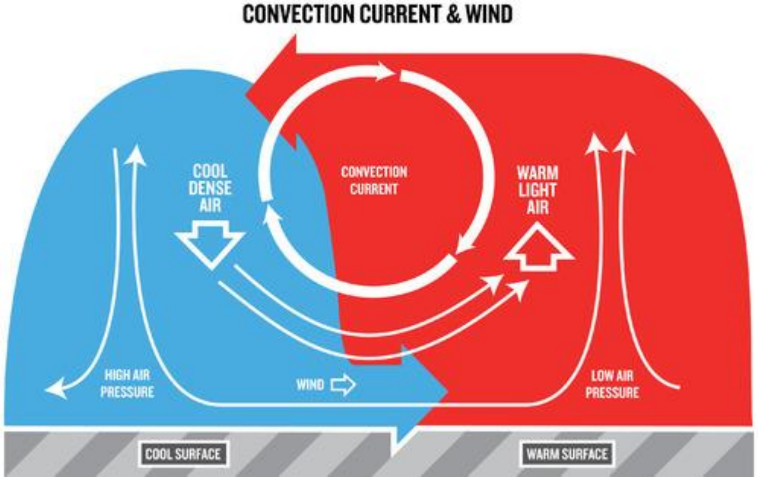
Convection occurs when fluids (liquids or gases) move around due to temperature differences

Hot Air __rises_____

Cold Air _sinks_____

Where should I roast my marshmallow?

Convection

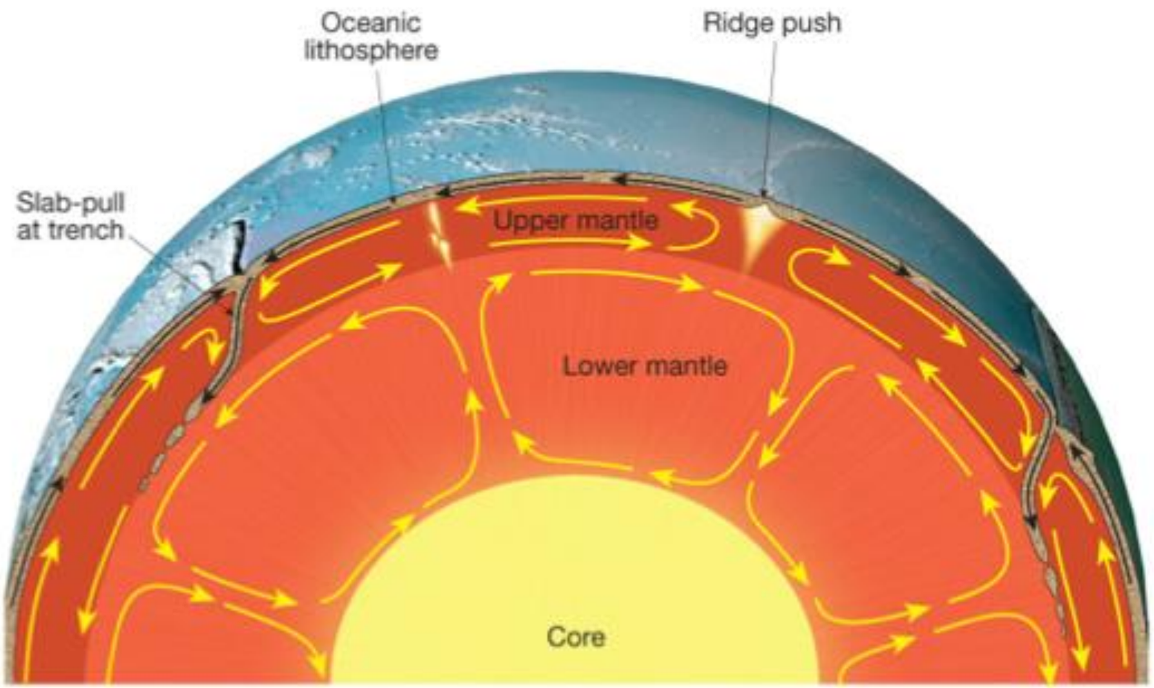


Why does hot air rise?

High Temperature
High Volume

High Volume
Same Mass
Lower Density

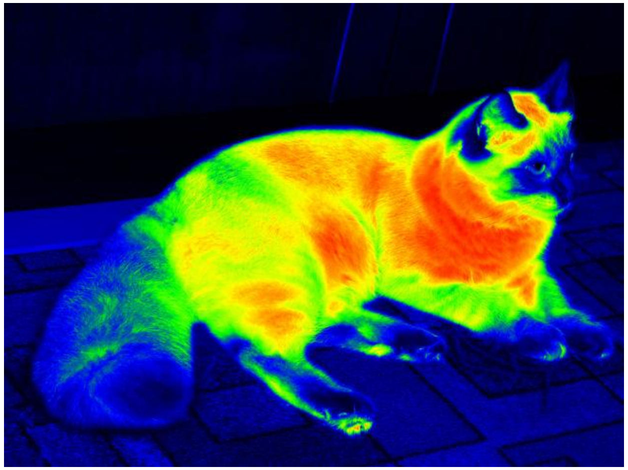
Convection

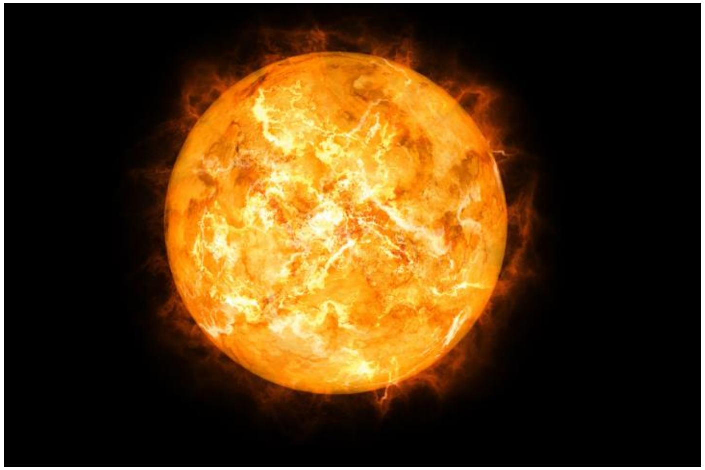

Oceanic lithosphere
Ridge push
Slab-pull at trench
Upper mantle
Lower mantle
Core


MATHMOS

Radiation

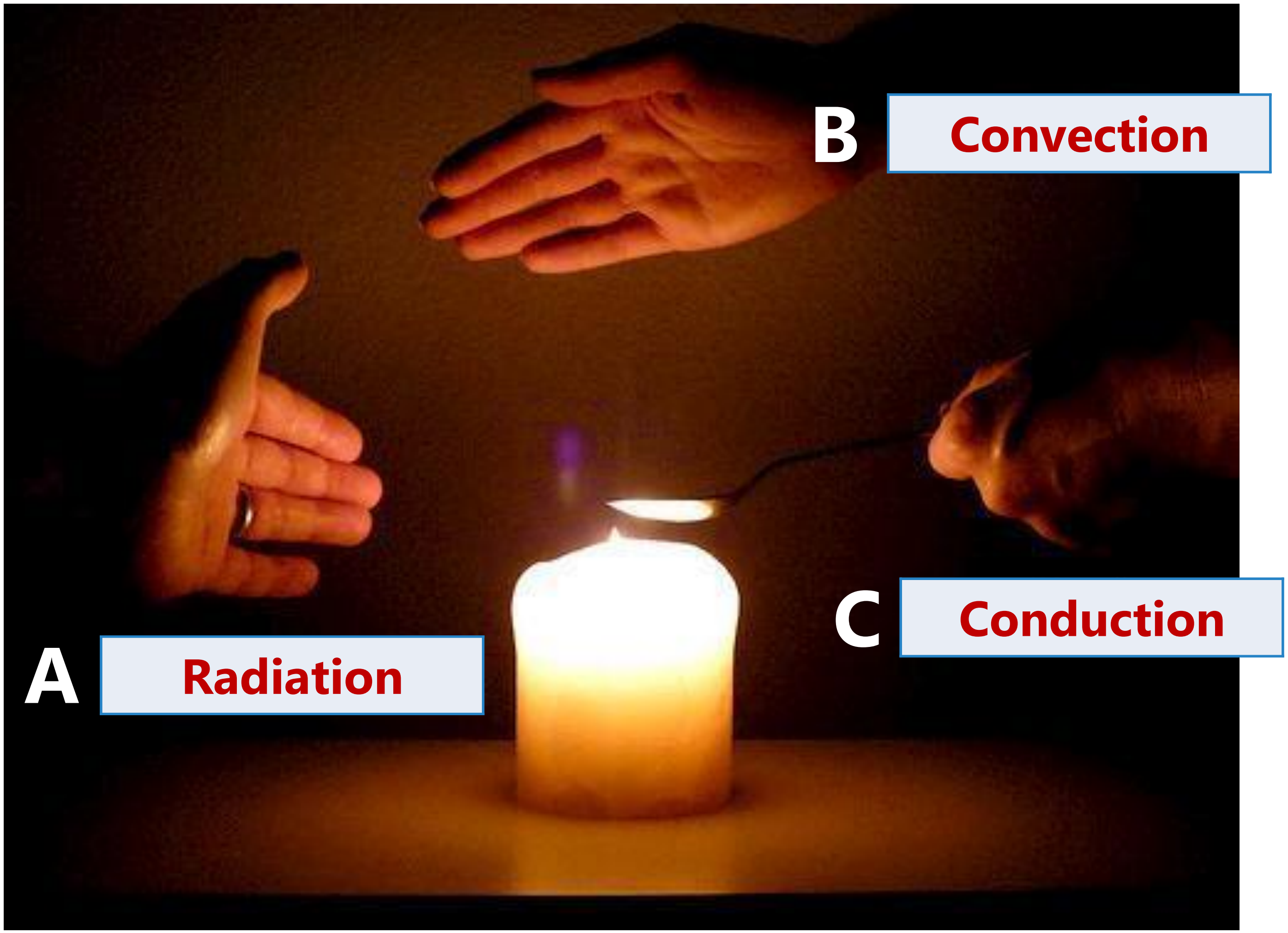
Radiation is energy that is transferred as waves such as visible light and infrared





Radiation can travel through ____a vacuum____

Label Me



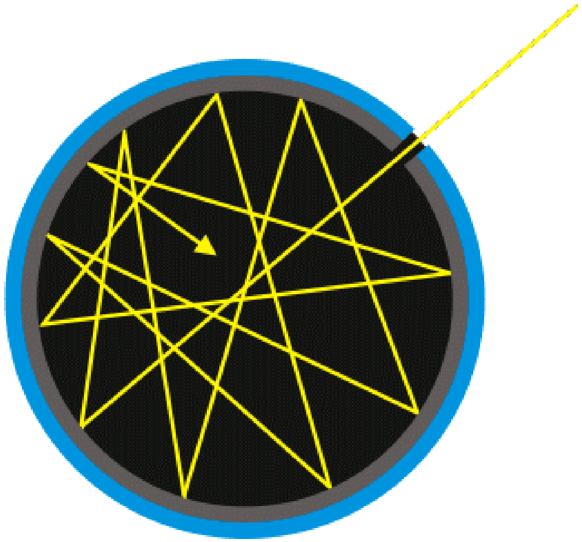
Emissivity

What color car heats up the most in the sun?

Black – Absorbs more light

Black Body Radiator

A black body radiator is an object that is perfectly opaque and absorbs all energy



Conceptual Black Body

Emissivity

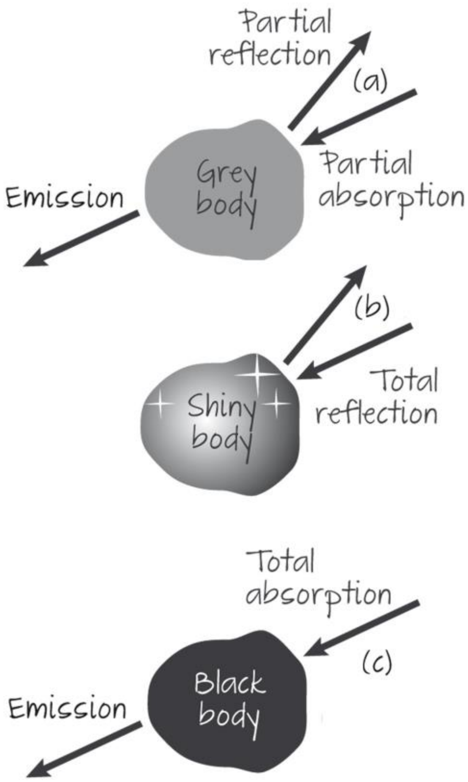
Emissivity	e	$\frac{power\ radiated\ by\ a\ surface}{power\ radiated\ from\ a\ black\ body\ of\ the\ same\ temperature\ and\ area}$

The emissivity is used to adjust for an object that isn't a perfect black-body radiator

This value is always between 0 and 1

$e \approx$ **1**

$e \approx$ **0.6**



Stefan-Boltzmann Law

$$P = e\sigma A T^4$$

Power [W]

e is usually = 1

5.67×10^{-8} W m^{-2} K^{-4}

Surface Area [m^2]

Absolute Temperature [K]

$A_{sphere} = 4\pi r^2$

Emissivity	e	$\dfrac{\text{power radiated by a surface}}{\text{power radiated from a black body of the same temperature and area}}$
Stefan-Boltzmann Constant	σ	5.67×10^{-8} W m^{-2} K^{-4}

Try This

A star has a radius of 8.3×10^{7} m and a surface temperature of 7500°C. Calculate the power it emits.

$e = 1$

$\sigma = 5.67 \times 10^{-8}$ W m^{-2} K^{-4}

$A = 4\pi(8.3 \times 10^{7})^{2} = 8.66 \times 10^{16}$ m^{2}

$T = 7500 + 273 = 7773$ K

$$P = e\sigma AT^{4}$$

$$P = (1)(5.67 \times 10^{-8})(8.66 \times 10^{16})(7773)^{4}$$

$$P = \mathbf{1.79 \times 10^{25}\ W}$$

Proportionality

How much more heat energy is radiated from a 80°C cup of water than from a 20°C cup of water?

$$P = e\sigma AT^4$$

**Careful! Temperature must be converted into Kelvin*

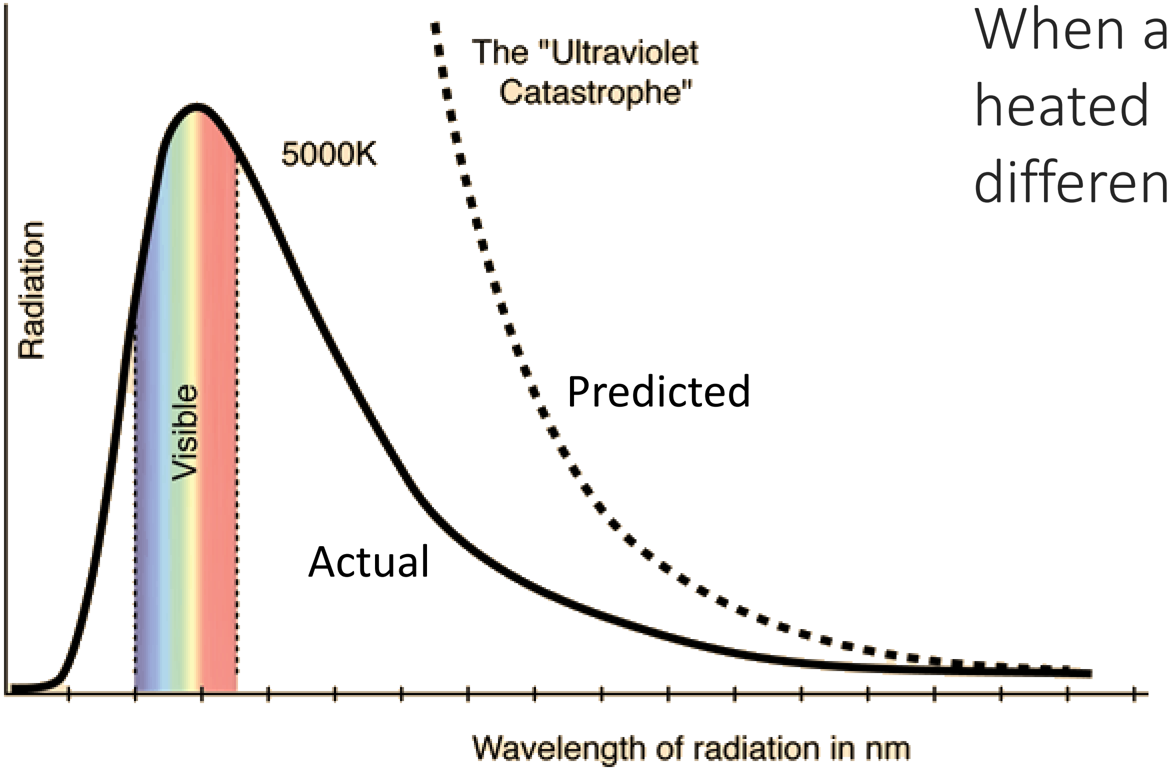
$$T_1 = 80 + 273 = 353\ \mathrm{K}$$

$$T_2 = 20 + 273 = 293\ \mathrm{K}$$

e, σ, and A are all the same before and after…

$$\frac{P_1}{P_2} = \frac{\cancel{e}\cancel{\sigma}\cancel{A}{T_1}^4}{\cancel{e}\cancel{\sigma}\cancel{A}{T_2}^4} = \frac{353^4}{293^4} = 2.1\ times\ more$$

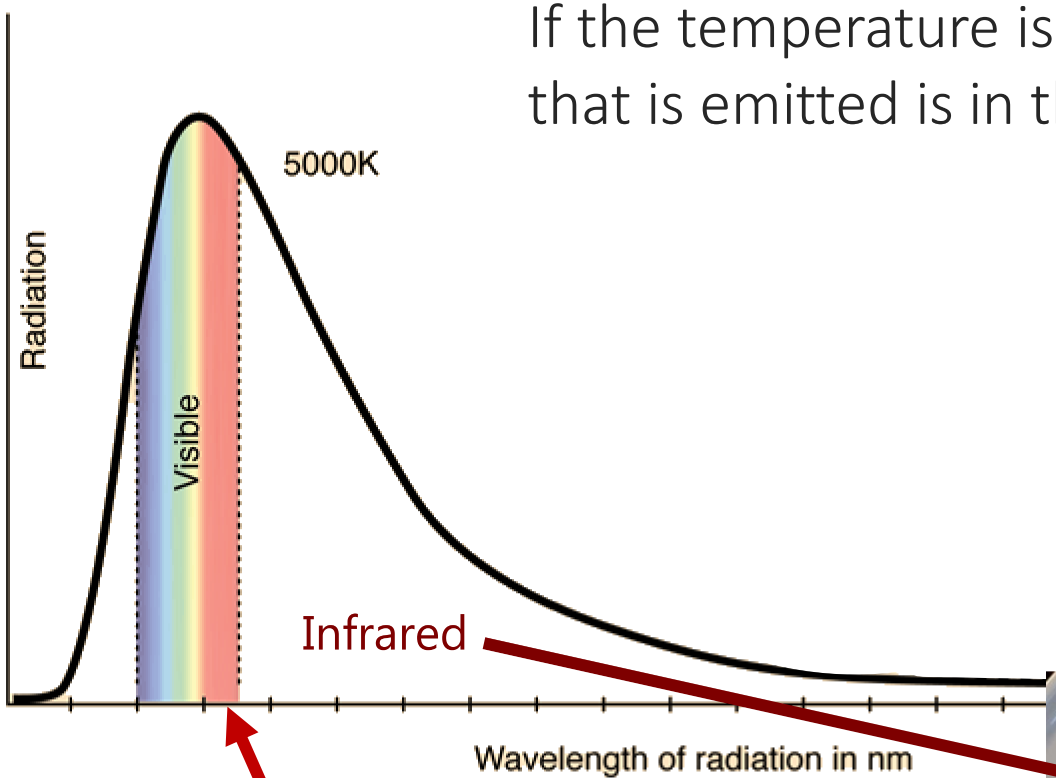
Radiated Energy



When a black body radiator is heated up, it emits a range of different wavelengths

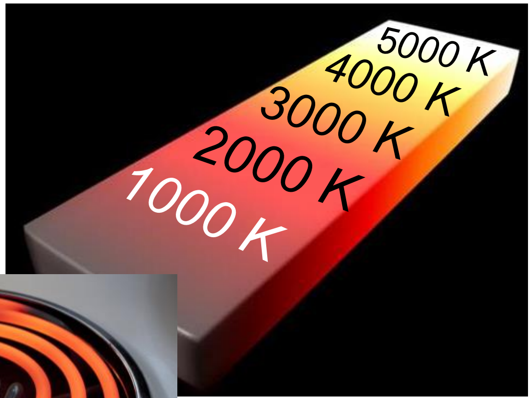
Glowing Hot

If the temperature is high enough the radiation that is emitted is in the visible spectrum



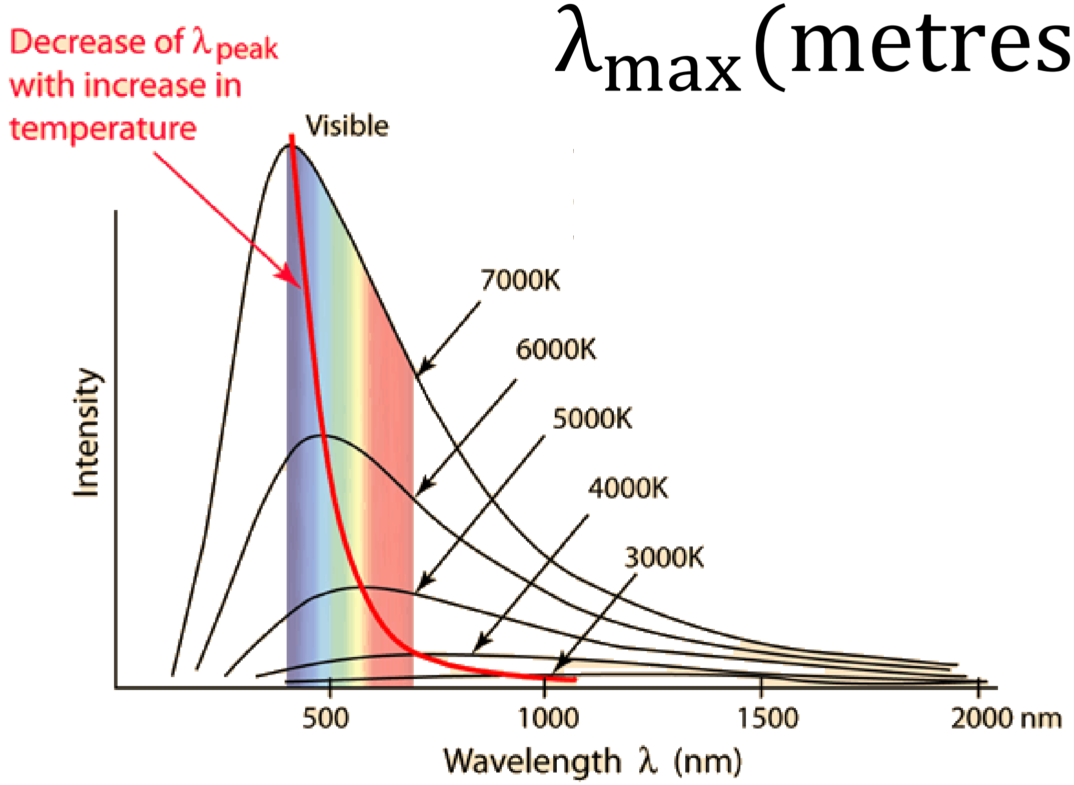
Infrared

Visible
Red Light



Wien's Displacement Law

$$\lambda_{max}(\text{metres}) = \frac{2.90 \times 10^{-3}}{\text{T (kelvin)}}$$



*Note: This assumes perfect blackbody radiation

Try This

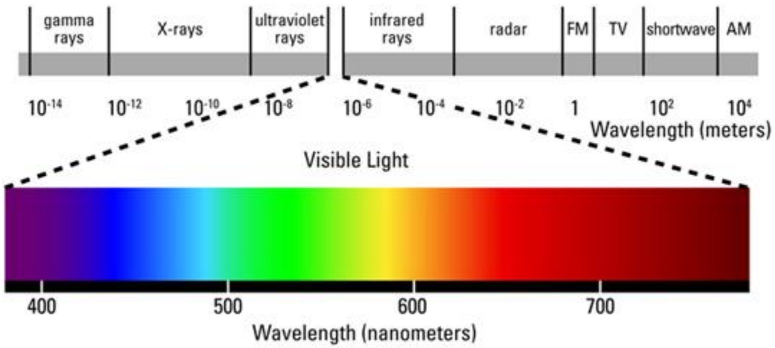
$$\lambda_{max}(\text{metres}) = \frac{2.90 \times 10^{-3}}{\text{T (kelvin)}}$$

At what wavelength is the emitted radiation of the Sun maximized if it has a surface temperature of 5780 K?

$$\lambda = \frac{2.90 \times 10^{-3}}{5780} = 5.02 \times 10^{-7}\text{m} = \boxed{502\text{ nm}}$$

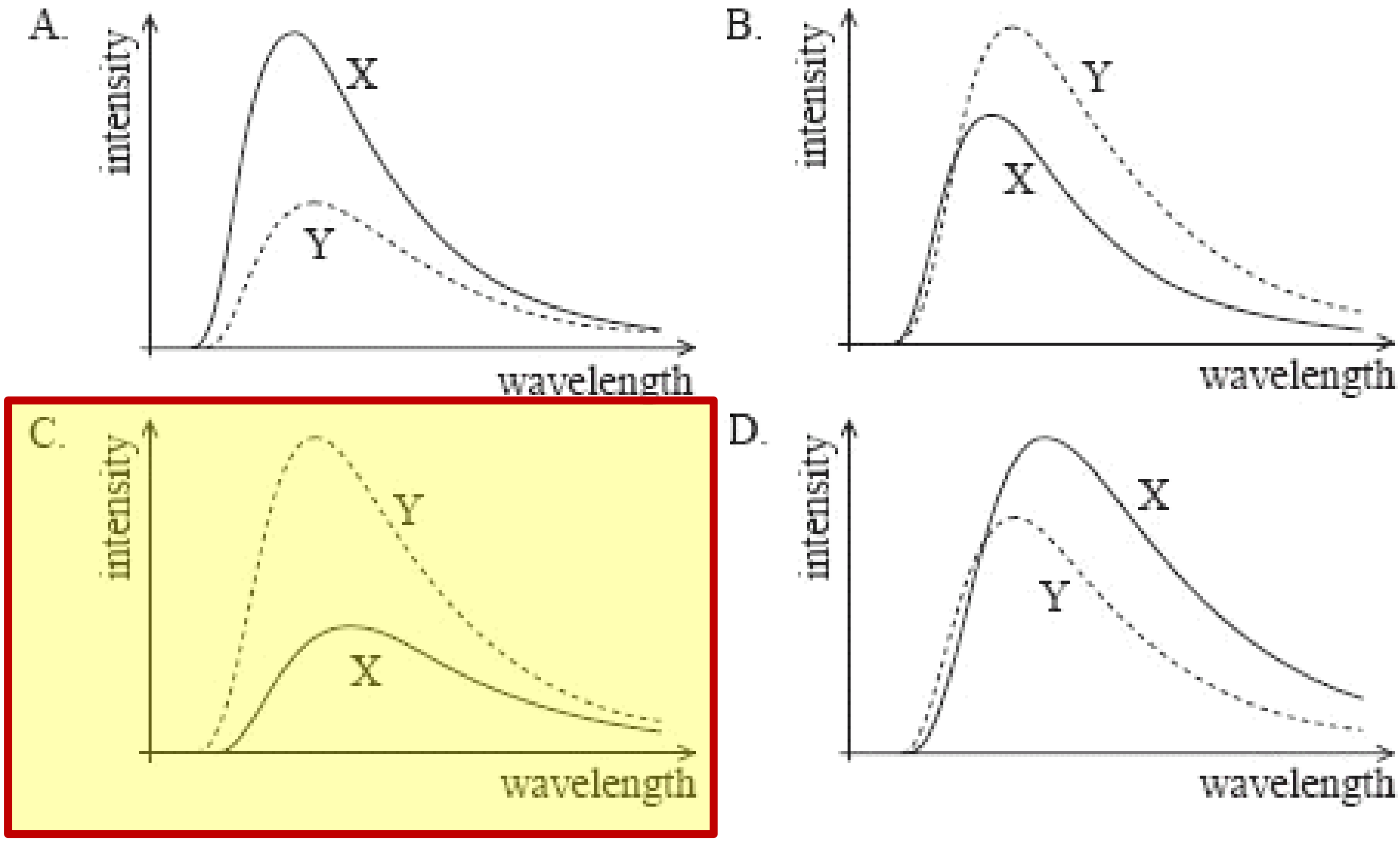
What is the most prevalent color of sunlight?

Green



Sample IB Question

Two black bodies X and Y are at different temperatures. The temperature of body Y is higher than that of body X. Which of the following shows the black body spectra for the two bodies?



Takeaways from Today

Know the difference between:

- Conduction
- Convection
- Radiation

Black Body Radiators

Emissivity

Stefan-Boltzmann Law

$$P = e\sigma A T^4$$

Wien's Displacement Law

$$\lambda_{max}(\text{metres}) = \frac{2.90 \times 10^{-3}}{\text{T (kelvin)}}$$