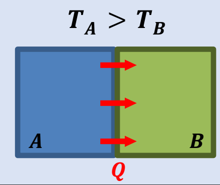
CONCEPT: INTRODUCTION TO HEAT TRANSFER

● Remember, HEAT is a *transfer* of thermal energy from one substance to another. There are 3 ways heat is transferred:

● **CONDUCTION**: ____________ transfer of heat between substances at different temperatures via ____________

- *Example*: Touching a boiling pot of water
- This was how heat was transferred in calorimetry problems



● **CONVECTION**: ______________ transfer of heat by heating a _________ surrounding the hot substance

- The heated fluid ___________ due to increased buoyancy and carries heat upwards with it
- *Example*: A candle flame heats the air around it, which rises
- Governed by complicated equations you won't need to know

● **RADIATION**: ______________ transfer of heat by emitting ________________________________

- These waves carry an energy _____________ to the heat lost by the substance
- *Example*: The heat you feel from the glowing filament in a lightbulb, or the Sun!

CONCEPT: CONDUCTION

● Remember! Conduction is the transfer of heat through ______________________

- Conduction is the most common type of heat transfer you will encounter in your studies
- When studying calorimetry, all heat transfers were via conduction

● What we are interested in is how RAPIDLY heat can be conducted from a HOT substance to a COLD substance

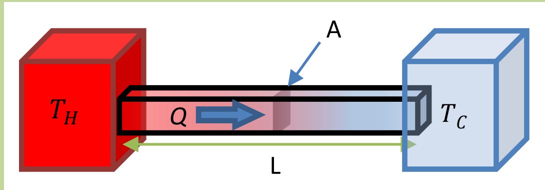
- Hot and cold are relative terms – all we mean is one is at a higher temperature than the other

● Materials have a natural allowance for heat flow, known as the THERMAL CONDUCTIVITY, $\boldsymbol{k}$

- The larger the thermal conductivity, the [SLOWER / FASTER] heat is conducted

● The CONDUCTION CURRENT is given by

$\boldsymbol{H} =$ ________________



- The conduction current is the rate at which heat is conducted through a substance
- The heat conducted would be given by $\boldsymbol{Q} =$ ________ so long as $\boldsymbol{H}$ is constant
- The conduction current CHANGES as the hot substance becomes cooler and the cold substance becomes hotter

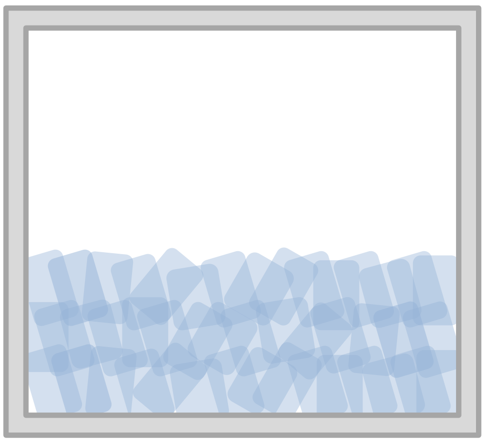
● The conduction current will be a CONSTANT if the hot and cold substances are ________________

- A RESERVOIR is an infinite source/sink of heat – it can absorb/release an infinite amount of heat with $\Delta T = 0$

EXAMPLE: A hot reservoir at 100°C is connected to a cold reservoir at 0°C by a 15 cm long piece of iron with a 0.05 m^2 cross section. How much heat crosses the piece of iron in 5 s? The thermal conductivity of iron is 79.5 W/mK.

PRACTICE: ICE MELTING IN A STYROFOAM COOLER

A cubic Styrofoam cooler containing ice on a hot day is shown in the following figure. The thickness of each wall of the cooler is 15 mm, with a side length of 1 m. If it is 40°C outside, how long will 2 kg of ice last in the cooler? Assume that during the melting process, the temperature inside the cooler remains at 0°C and that no heat enters from the bottom of the cooler. Note that the latent heat of fusion for water is 334 kJ/kg and the thermal conductivity of Styrofoam is 0.033 W/mK.



CONCEPT: RADIATION

● Remember! Certain hot objects can expend heat in the form of emitted electromagnetic radiation

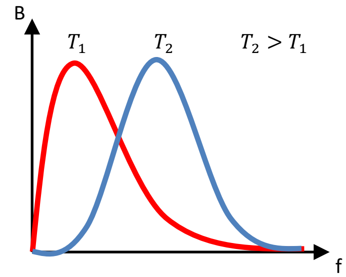
- Substances that emit thermal radiation are known as ____________________ or ________________________

● As with all waves, a particular electromagnetic wave is defined by its frequency (or its wavelength)

- For light (electromagnetic waves), a particular frequency will be referred to as its _____________

● Blackbodies do not emit light at a single color, but emit light across a SPECTRUM of colors

- The particular color spectrum depends on the temperature of the light
- The color of light that is seen is the brightest color emitted
- As temperatures increase, the light shifts from __________ to __________
- At very high temperatures, the light shifts from __________to __________



● The RADIANCE OF RADIATION EMITTED by a blackbody-like object is given by the Stefan-Boltzmann Law

$\boldsymbol{j} =$ ___________________ where ϵ is the EMISSIVITY – $\epsilon = 1$ for a true blackbody

- $\boldsymbol{\sigma}$ is known as the Stefan-Boltzmann constant, and is $\sigma = 5.67 \times 10^{-8}\ W/m^2K^4$
- RADIANCE is the power per unit surface area of the object emitting the thermal radiation
    - Radiance is DIFFERENT than intensity, though they share units, W/m^2

● The brightest color in the emission spectrum is given by WEIN'S DISPLACEMENT LAW

- $\boldsymbol{b} = 2.9 \times 10^{-3}\ mK$ is Wein's displacement constant

$\boldsymbol{\lambda_{Bright}} =$ _________

<u>EXAMPLE</u>: A spherical object of 0.01 m radius with an emissivity of 0.8 is heated to a temperature of 1000 K. How much heat is radiated by this object in 5 ms? What is the brightest color of the radiation? Assume that during these 5 ms, the temperature of the object does not change.

PRACTICE: SURFACE TEMPERATURE OF THE SUN

If the intensity of sunlight measured at the Earth's surface is 1400 W/m^2, what is the surface temperature of the Sun? Treat the Sun like a true blackbody. Note that the distance from the Earth to the Sun is 1.5×10^{11} m and the radius of the Sun is 696 million meters.