

## Note on Posted Slides

- These are the slides that I intended to show in class on Mon. Feb. 25, 2013.
- They contain important ideas and questions from your reading.
- Due to time constraints, I was probably not able to show all the slides during class.
- They are all posted here for completeness.

## PHY205H1S Physics of Everyday Life Class 12: **Heat**

- Conduction
- Convection
- Radiation
- Newton's Law of Cooling
- Global Warming and Greenhouse Effect



[image from <http://petticoatsandpistols.com/2008/05/21/knee-steppin-barbecue/> ]

2:10pm

### Chapter 16 Pre-class reading question

- Which of the following most prevents the escape of terrestrial radiation (infrared)?
  - A. Carbon monoxide
  - B. Air
  - C. Carbon dioxide
  - D. Molecular nitrogen
  - E. Molecular oxygen

2:11pm

### Chapter 16 Pre-class reading question

- The relation  $f \sim T$  tells us that high-temperature sources emit electromagnetic waves of
  - A. low frequency
  - B. high penetrating power
  - C. high frequency
  - D. long wavelengths

5:10pm

### Chapter 16 Pre-class reading question

- When your foot stands on a tile floor, thermal energy always flows
  - A. from the tile to your foot
  - B. from your foot to the tile
  - C. upward
  - D. downward
  - E. from either your foot or the tile depending on the temperatures of the tile and your foot

5:11pm

### Chapter 16 Pre-class reading question

- A good absorber of radiation is a
  - A. good reflector.
  - B. poor emitter of radiation.
  - C. good emitter of radiation.

## Heat Transfer

Objects in thermal contact at different temperatures tend to reach a common temperature in three ways:

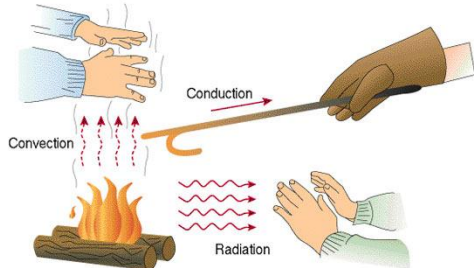


Image from Beedrom.com Copyright Ecowave S.A.S. 2016-2019. <http://beedrom.com>

## Conduction

- Transfer of internal energy by electron and molecular collisions within a substance, especially a solid



### Conduction CHECK YOUR NEIGHBOR

If you hold one end of a metal bar against a piece of ice, the end in your hand will soon become cold. Does cold flow from the ice to your hand?

- Yes
- In some cases, yes
- No
- In some cases, no

## Conduction

### Conductors

- Good conductors conduct heat quickly.
    - Substances with loosely held electrons transfer energy quickly to other electrons throughout the solid.
- Example: Silver, copper, and other solid metals



Image of teapot downloaded Feb. 1 2013 from [http://gallery.nor.gov.uk/zoom52720\\_1726.html](http://gallery.nor.gov.uk/zoom52720_1726.html)

## Conduction



- Poor conductors are insulators.
    - molecules with tightly held electrons in a substance vibrate in place and transfer energy slowly—these are good insulators (and poor conductors).
- Examples: Glass, wool, wood, paper, cork, plastic foam, air

Image downloaded Feb. 1 2013 from <http://www.functionalmag.com/blog/2014/1/office-science-reveler/>

### Insulation

- Doesn't *prevent* the flow of internal energy
  - *Slows* the rate at which internal energy flows
- Example: Rock wool or fiberglass between walls slows the transfer of internal energy from a warm house to a cool exterior in winter, and the reverse in summer.



Image downloaded Feb. 1 2013 from <http://owners.coming.com/products/insulation/insulation201004.aspx>

## Conduction

- Insulation (continued)

Dramatic example: Walking barefoot without burning feet on red-hot coals is due to poor conduction between coals and feet.

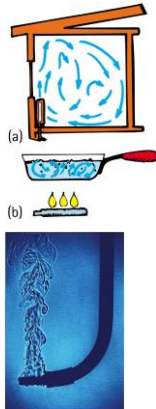


## Convection

- Transfer of heat involving only bulk motion of fluids

Examples:

- Visible shimmer of air above a hot stove or above asphalt on a hot day
- Visible shimmers in water due to temperature difference



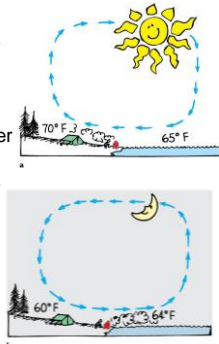
## Winds

- Result of uneven heating of the air near the ground

– Absorption of Sun's energy occurs more readily on different parts of Earth's surface.

- Sea breeze

- The ground warms more than water in the daytime.
- Warm air close to the ground rises and is replaced by cooler air from above the water.
- At night the ground cools faster, and the cycle is reversed



## Liquid Nitrogen

- Molecular Nitrogen,  $N_2$ , composes 70% of the air we breath
- Below  $-196^\circ\text{C}$  (77 Kelvin), Nitrogen is liquid
- We have a big tank of liquid nitrogen (LN2) at the North end of this building
- We use it to cool things to study materials – Condensed Matter Physics research
- It is also good at parties to quickly cool beer

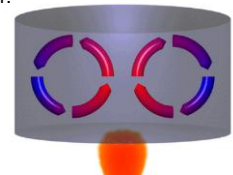


## Convection

Reason warm air rises

- Warm air expands, becomes less dense, and is buoyed upward.
- It rises until its density equals that of the surrounding air.

Example: Smoke from a fire rises and blends with the surrounding cool air.



[animation from [http://brsscience6209.ed44ops.org/files/2010/10/Convection\\_1485321.gif](http://brsscience6209.ed44ops.org/files/2010/10/Convection_1485321.gif) ]

## Convection CHECK YOUR NEIGHBOR

Although warm air rises, why are mountaintops cold and snow covered, while the valleys below are relatively warm and green?

- Warm air cools when rising.
- There is a thick insulating blanket of air above valleys.
- Both A and B.
- None of the above.



[image of Mt. Kilimanjaro from <http://www.amycharity.com/backyardlife/> ]

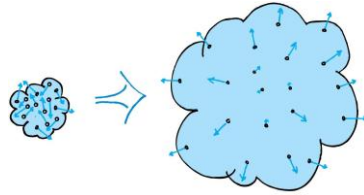
### Cooling by expansion

- Opposite to the warming that occurs when air is compressed



Example: The “cloudy” region above hot steam issuing from the nozzle of a pressure cooker is cool to the touch (a combination of air expansion and mixing with cooler surrounding air). Careful, the part at the nozzle that you can’t see is steam—ouch!

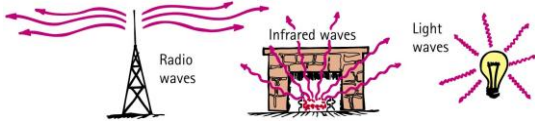
### Gas Cooling By Expansion



- Molecules in a region of expanding gas collide more often with receding molecules than with approaching ones
- Their rebound speeds therefore tend to decrease, and, as a result, the expanding gas cools.
- This phenomenon is used in refrigerators, which use cooled coils to remove heat from a low temperature environment

### Radiation

- Transfer of energy via electromagnetic waves such as light or infrared.



### Radiation CHECK YOUR NEIGHBOR

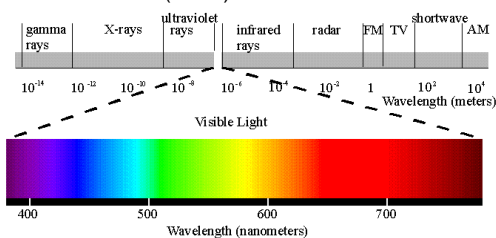
The surface of Earth loses energy to outer space due mostly to

- conduction.
- convection.
- radiation.
- radioactivity.

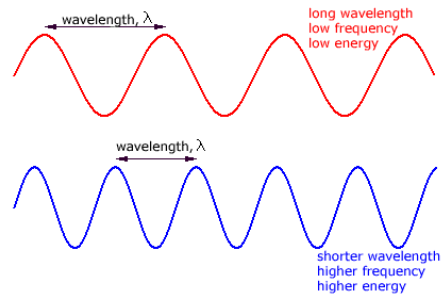


### Radiation

- Transferred energy
- Exists as electromagnetic waves ranging from long (radio waves) to short wavelengths (X-rays)
- In visible region, ranges from long waves (red) to short waves (violet)



### Wavelength and Frequency



Electromagnetic Waves

**Radiation**  
CHECK YOUR NEIGHBOR

Which body glows with electromagnetic waves?

- A. Sun
- B. Earth
- C. Both A and B.
- D. None of the above.

**Radiation**

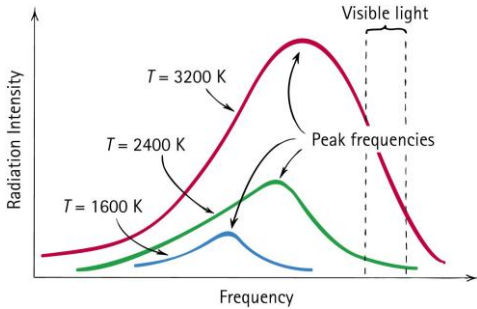
- Every object above absolute zero radiates.
- From the Sun’s surface comes **visible** light, or solar radiation, which we can see.
- From the Earth’s surface comes terrestrial radiation in the form of **infrared** waves below our threshold of sight.



Image downloaded Feb. 12 2013 from <http://www.fropgoeb.com/user/profile/compshots/detail.html?username1>

**Blackbody Radiation**

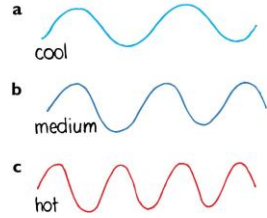
- Frequency of radiation is proportional to the absolute temperature of the source ( $\bar{f} \sim T$ ).



**Radiation**

**Range of temperatures of radiating objects**

- Room-temperature emission is in the infrared.
- Temperature above 500°C, red light emitted, longest waves visible.
- About 600°C, yellow light emitted.
- At 1500°C, object emits white light (whole range of visible light).



**Radiation**  
CHECK YOUR NEIGHBOR

Which is the better statement?

- A. A black object absorbs energy well.
- B. An object that absorbs energy well is black.

**Radiation**  
CHECK YOUR NEIGHBOR

Which melts faster in sunshine—dirty snow or clean snow?

- A. Dirty snow
- B. Clean snow
- C. Both A and B.
- D. None of the above.



## Absorption and Emission

- Any material that absorbs more than it emits is a net absorber.
- Any material that emits more than it absorbs is a net emitter.
- Net absorption or emission is relative to temperature of surroundings.
- Good absorbers are good emitters
- Poor absorbers are poor emitters

[Image from [http://www.starbucks.co.uk/starbucks\\_blog/04\\_10\\_08/04\\_10\\_08\\_01.html](http://www.starbucks.co.uk/starbucks_blog/04_10_08/04_10_08_01.html)]

## Reflection of radiant energy

- Any surface that reflects very little or no radiant energy looks dark

Examples of dark objects: eye pupils, open ends of pipes in a stack, open doorways or windows of distant houses in the daytime

- Good reflectors are poor absorbers.
- Poor absorbers are poor emitters.
- A white container will radiate heat more slowly than a black container



## Radiation CHECK YOUR NEIGHBOR

A hot pizza placed in the snow is a net

- A. absorber.
- B. emitter.
- D. neither

## Newton's law of cooling:

$$\text{Rate of cooling} \sim \Delta T$$

- Rate is proportional to the temperature difference,  $\Delta T$ , between the object and its surroundings
  - Also applies to rate of warming
- Examples:
- Warmer house leaks more internal energy to the outside than a house that is less warm.
  - Frozen food will warm faster in a warm room than in a cold room.



[Image downloaded Feb. 12 2013 from [http://www.starbucks.co.uk/starbucks\\_blog/05\\_10\\_08/05\\_10\\_08\\_01.html](http://www.starbucks.co.uk/starbucks_blog/05_10_08/05_10_08_01.html)]

## When to add cream to coffee...

- Psy likes to drink his coffee hot, and he likes cream in his coffee. He buys it at Starbucks but does not want to drink it until he gets to his home, which is a 5 minute walk. To keep the coffee as hot as possible, should he add the cream at Starbucks or at home?
- A. Starbucks, before the 5-minute walk
  - B. At home, just before drinking
  - C. It doesn't matter



## When to add cream to coffee...

- Psy likes to drink his coffee hot, and he likes cream in his coffee. He buys it at Starbucks but does not want to drink it until he gets to his home, which is a 5 minute walk. To keep the coffee as hot as possible, should he add the cream at Starbucks or at home?
- Best student answer from the facebook discussion page:
  - "Starbucks. Because if we add cream at first, the temperature of the coffee decreases a little bit first, but can maintain this "hotness" longer than if we don't add cream at first. The reason is because the environment does not take as much heat from the creamed coffee."
  - This is because of Newton's Law of Cooling.
  - The higher is  $\Delta T$ , the greater the rate of heat loss to the environment. Adding cream cools the coffee and reduces  $\Delta T$ .

## When to add cream to coffee...

- My reasoning:
- When you add the cream to the coffee, it is going to decrease its temperature by some amount; this is about the same whether you do it at home or at Starbucks.
- When you carry the coffee through the environment for 5 minutes, it will be losing heat, since the coffee temperature is higher than the environment.
- The rate of heat loss over this 5 minutes is proportional to  $\Delta T$   $\Delta T = T_{\text{coffee}} - T_{\text{env}}$
- If you added the cream first,  $\Delta T$  is less while you carry it, so it is going to lose less heat en route.
- In the end, this leads to hotter coffee when you eventually drink it.

## Heat Transfer by Evaporation

- Fourth heat transfer mechanism, not mentioned in Hewitt
- Molecules in a liquid are continuously moving and jiggling against one another
- At the surface, sometimes a collision is such that a molecule ends up with enough energy to escape
- When the molecule leaves the liquid, it takes thermal energy with it, and so this is a mode of heat transfer



[Image from <http://www.gutenberg.org/files/10101/10101-h/10101-h.htm>]

## Greenhouse Gases

- The Earth's atmosphere contains mostly Nitrogen and Oxygen, both of which are transparent (non-absorbing) of both visible and infrared radiation
- Certain gases are *transparent* for visible radiation, but *absorbing* for infrared radiation
- These are called "greenhouse gases":
  - Carbon Dioxide
  - Water vapour
  - Methane
  - Nitrous oxide



[Image from [http://en.wikipedia.org/wiki/File:Exhaust\\_pipe\\_miller.JPG](http://en.wikipedia.org/wiki/File:Exhaust_pipe_miller.JPG)]

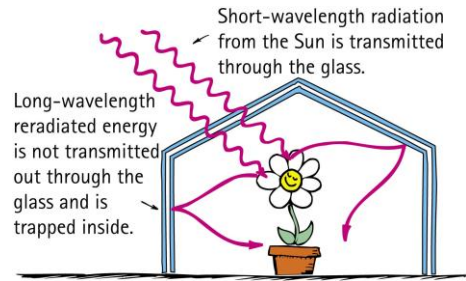
## Newton's Law of Cooling CHECK YOUR NEIGHBOR

It is commonly thought that a can of beverage will cool faster in the coldest part of a refrigerator. Knowledge of Newton's law of cooling

- supports this knowledge.
- shows this knowledge is false.
- may or may not support this knowledge.
- may or may not contradict this knowledge.

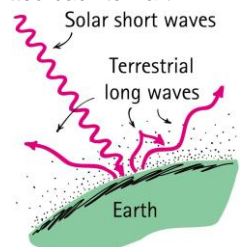
## Greenhouse effect

- Named for a similar temperature-raising effect in florists' greenhouses



## Greenhouse Effect on Earth

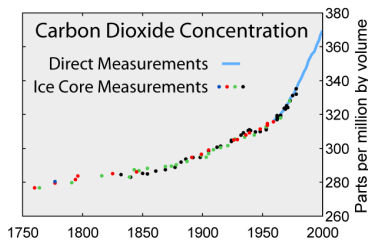
- Energy absorbed as visible light from the Sun
- Part reradiated by Earth as longer-wavelength infrared radiation
- Terrestrial radiation absorbed by atmospheric greenhouse gases and re-emitted back to Earth.
- Equilibrium temperature determined by concentration of greenhouse gases in the atmosphere
- More greenhouse gases means higher temperature earth



## Global Warming and the Greenhouse Effect CHECK YOUR NEIGHBOR

The "greenhouse gases" that contribute to global warming absorb

- A. more visible radiation than infrared.
- B. more infrared radiation than visible.
- C. visible and infrared radiation about equally.
- D. very little radiation of any kind.



- To examine times before systematic direct measurements began in 1958, scientists rely on data from bubbles trapped in polar ice cores.
- For the past several thousand years, up until the last couple of centuries, average CO<sub>2</sub> concentration hovered in the 250 to 280 ppmv range.
- [http://www.windows2universe.org/earth/climate/greenhouse\\_effect\\_gases.html](http://www.windows2universe.org/earth/climate/greenhouse_effect_gases.html)

## Solar Power



More energy from the sun hits Earth in 1 hour than all of the energy consumed by humans in an entire year.

— Nathan S. Lewis, California Institute of Technology

## Solar Research at U of T



- Ted Sargent is a professor in the Department of Electrical and Computer Engineering at U of T
- Dr. Sargent and his group are working on a paint-on solution that could turn almost any surface into a photovoltaic cell
- Because the particles in the coating are sensitive to infrared, the new cells could potentially capture twice as much solar energy
- The technology could even be applied to clothing. "Your jacket could be solar," speculates Dr. Sargent.

See more at <http://www.light.utoronto.ca/>

[image from [http://en.wikipedia.org/wiki/Deep\\_water\\_solar](http://en.wikipedia.org/wiki/Deep_water_solar)]

## Before class on Wednesday...

- Please read Chapter 19, or at least watch the 10-minute pre-class video for class 13.



- Something to think about:
- As some water waves pass you, your boat bobs up and down with a frequency of 0.5 Hz. What is the **period** of these waves?
- If the wavelength is 3 m, what is the **speed** of these waves?

