Announcements

- Mid-Term Exam #2 in 1 week, Thu Sep 30. Same format.

- TA will be giving lecture + Review on Tuesday.

- One more chance for evening observing tonight at 9pm

- Don’t forget to fill out your impressions in the final assignment on M.A.!

- HW #3 due Sunday at 11:45

- Finish reading 5.1–5.3
Last Night

- Sun passed through the celestial equator at 11pm last night.

- Sunrise: 7:30am, Sunset: 7:30pm — Equal Day and Night!
Last Night

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Sunrise: 7:30am, Sunset: 7:30pm — Equal Day and Night!

The Autumnal Equinox!!
Last Time

**Motion, and Gravity**

*All objects accelerated by gravity at the same rate.*

**Momentum: mass x velocity.**

**Force: changes momentum (including change in direction!).**
Last Time

Mass: Amount of matter, doesn’t change no matter where you are.

Weight: Force of gravity acting on an object. Changes (e.g. the moon).

“Weightlessness” same as “free-fall”. There is gravity in space, but you are falling freely around the earth.

Tides caused by moon “pulling” on near side of ocean more than earth, and earth more than far side of ocean. Strongest tides (“Spring”) when Moon + Sun work together.
Orbit as "Free-Fall": Fig. 4.4
Last Time

Newton’s Laws:

1. Object stays at rest or in constant motion unless acted on by some force.

2. Force = mass x acceleration.

3. For every force, equal and opposite force.

Conservations laws: Momentum, angular momentum, and energy.
Imagine that you throw a ball directly upward. Which of the following statements best describes how Newton’s Second Law accounts for the motion of the ball when it reaches its maximum height?

A) **The ball has a velocity that is zero and an acceleration that is zero.**
B) **The ball has a velocity that is upward and an acceleration that is downward.**
C) **The ball has a net force that is downward and an acceleration that is downward.**
D) **The ball has a net force that is downward and a velocity that is downward.**
E) **The ball has a net force that is downward and an acceleration of zero.**
Imagine that you throw a ball directly upward. Which of the following statements best describes how Newton’s Second Law accounts for the motion of the ball when it reaches its maximum height?

A) The ball has a velocity that is zero and an acceleration that is zero.

B) The ball has a velocity that is upward and an acceleration that is downward.

C) The ball has a net force that is downward and an acceleration that is downward.

D) The ball has a net force that is downward and a velocity that is downward.

E) The ball has a net force that is downward and an acceleration of zero.
Beyond our neighborhood

Nearby

Soon we’ll cover the residents of the Solar system.

We can reach planets, moons, comets and asteroids using satellites, landers, dig the soil, etc.

Far!

Move beyond the solar system to study stars & galaxies. Much too far to visit.

How can we learn about them?

Expand our toolset. Use light!

Thursday, September 23, 2010
Light

- Carries information across the universe.

- To understand objects we study (stars, galaxies), we want to know what they are made of, but we can’t visit...

- We need to know how light and matter interact!
What is light?

- Light is composed of all the colors of the rainbow.

- There is light beyond the colors of the rainbow (your eyes just cannot see it).

- What our eyes can see is called “visible light” or “optical light.”
What is light?

Light can behave both as a wave and a particle depending on how you look at it.

We call this the "wave/particle duality" of light.
Wave Nature of Light

Sometimes light acts like a wave.

Definitions:

- **Wavelength**: distance between adjacent peaks
- **Frequency**: the number of times any piece of the rope moves up and down in a second (Hz)
Wave Nature of Light

- **Light is an electromagnetic wave (EM) that travels at the speed of light.**

- **The strength of (invisible) electric and magnetic fields is what varies.**

- **A line of electrons would wiggle if an electromagnetic wave passed by.**
Units again!

- The wavelength of visible light is very small.

- Red light has a wavelength of roughly $670 \times 10^{-9}$ m or 670 nm.

- The width of a human hair is 10,000 nm!

- Frequency measured in Hz (1/s).
Wavelengths of the Rainbow

Visible Light

Wavelength (nanometers)

Gamma rays

X-rays

Ultraviolet rays

Infrared rays

Radar

FM

TV

Shortwave

AM

$10^{-14}$

$10^{-12}$

$10^{-10}$

$10^{-8}$

$10^{-6}$

$10^{-4}$

$10^{-2}$

1

$10^{2}$

$10^{4}$

Wavelength (meters)

Human eye sensitivity
Frequency vs. Wavelength

Because the speed of light is fixed:

- The longer the wavelength, the lower the frequency
- The shorter the wavelength, the higher the frequency
Particle Nature of Light

- Light can also be thought of as consisting of particles, known as “photons”

- Photon: A “unit” of light with a specific wavelength, frequency, and energy. A localized “wave packet”

- The higher the frequency, the higher the energy

- Einstein (1905) won the Nobel prize for this discovery (Not relativity!)
The Electromagnetic Spectrum

gamma rays  X-rays  ultraviolet  infrared  radio

visible  microwaves

shorter  longer

wavelength (meters)

10^{-12}  10^{-10}  10^{-8}  10^{-6}  10^{-4}  10^{-2}  1

higher  lower

frequency (hertz)

10^{20}  10^{18}  10^{16}  10^{14}  10^{12}  10^{10}  10^{8}

10^{6}  10^{4}  10^{2}  1  10^{-2}  10^{-4}  10^{-6}  10^{-8}

energy (electron-volts)

radioactive elements  X-ray machines  light bulb  people  radar  microwave oven  radio transmitter

gamma ray burst  black hole accretion disk  Sun's chromosphere  Sun  planets, star-forming clouds  cosmic microwave background  radio galaxy
Properties of Light

- **Color**
  - **Depends on frequency**
  - Blue = high frequency = short wavelength
  - Red = low frequency = long wavelength

- **Carries energy (heat)**

- **Photon energy**
  - \[ E = hf \]
  - \( h = \text{Planck's constant} \)
  - High frequency = high energy = blue
  - Low frequency = low energy = red
This is not an ordinary camera....
Infrared: light of heat
INFRARED: LIGHT OF HEAT
INFRARED: LIGHT OF HEAT
Infrared Zoo

NASA/IPAC

93.2

68.2

NASA/IPAC

93.1

66.0

NASA/IPAC

93.7

73.0

Thursday, September 23, 2010
Propagation of Light

- Photons travel in straight lines:
- Energy spread over larger area at larger distances
- Produces $1/r^2$ decrease in brightness: double distance - brightness decreases by 4

Thursday, September 23, 2010
Which of the following is not a form of light?

A) Radio waves
B) Microwaves
C) X-rays
D) All of the above are a form of light.
E) None of the above is a form of light.
Which of the following is **not** a form of light?

A) Radio waves  
B) Microwaves  
C) X-rays  
D) All of the above are a form of light.  
E) None of the above is a form of light.
Which of the following has the least energy?

A) Radio waves
B) Visible light
C) X-rays
D) Infrared
E) They all have the same energy.
Which of the following has the least energy?

A) radio waves
B) Visible light
C) x-rays
D) Infrared
E) They all have the same energy.
What is matter?

All matter is made up of various chemical elements such as hydrogen, helium, carbon, oxygen, neon, iron, gold, etc.

Each element made up of different atoms.
Atoms are composed of protons, neutrons, and electrons.

- **Protons** = +
- **Electrons** = -
- **Neutrons** = neutral

Atoms are discovered at the turn of the 19th century.

Ten million atoms could fit end to end across this dot.

The nucleus is nearly 100,000 times smaller than the atom but contains nearly all of its mass.

Atom: Electrons are “smeared out” in a cloud around the nucleus.

Nucleus: Contains positively charged protons (red) and neutral neutrons (gray).

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**Atomic Terminology**

- **Atomic Number:** # protons in a nucleus
- **Atomic Mass Number:** # protons + neutrons

- **Hydrogen (\(^1\text{H}\))**
  - Atomic number: 1
  - Atomic mass number: 1
  - (1 electron)

- **Helium (\(^4\text{He}\))**
  - Atomic number: 2
  - Atomic mass number: 4
  - (2 electrons)

- **Carbon (\(^{12}\text{C}\))**
  - Atomic number: 6
  - Atomic mass number: 12
  - (6 electrons)

The number of electrons in a neutral atom equals its atomic number.
**Atomic Terminology**

- **Isotopes:** Same # of protons, different # of neutrons ($^4\text{He}$, $^3\text{He}$)

![Diagram of Isotopes of Carbon](image)
How do light and matter interact?

- Emission (matter gives off light)
- Absorption (matter absorbs light) 
  OPAQUE: absorbs light.
- Reflection or Scattering (light bounces off matter).
Interaction of Light and Matter

- **Light bulb emits white light.**
- **Mirror reflects light.**
- **Special cells in human eye absorb light.**
- **Glass transmits light.**
- **Sun emits light.**

- **Red Chair**
  Absorbs all colors except red.
  Reflects (scatters) red.

- **Blue Shirt**
  Absorbs all colors except blue.
  Reflects (scatters) blue.

- **Snow**
  Absorbs some light, which aids melting.
  Scatters most light, so it looks bright.

- **Ground**
  Absorbs some light (heats it up).
  Scatters some light (which is how we see it).

- **Tree**
  Absorbs all colors except green.
  Reflects (scatters) green.

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**Interaction of Light and Matter**

- **We can learn about matter from the light that it emits or reflects**

**Example:**

- **The leaves in a green tree must absorb all other colors**

- **The matter in a window must be transparent to light**

- **A red filter absorbs all other colors than red.**
THE FILTER EXPERIMENT

- A red object absorbs all but red light.
- A red filter transmits only red light.
Why is a red rose red?

A) The rose absorbs red light
B) The rose transmits red light
C) The rose emits red light
D) The rose reflects red light
**Why is a red rose red?**

A) **The rose absorbs red light**

B) **The rose transmits red light**

C) **The rose emits red light**

D) **The rose reflects red light**
What is a Spectrum?

A spectrum tells you the intensity of a given wavelength of light over a range of wavelengths.
BLACKBODY RADIATION

A perfect absorber is “black”

Absorbs all light shining on it

Absorbed light (energy) heats object

Temperature increases until:

\[\text{emitted energy} = \text{absorbed energy}\]

Emitted radiation called Blackbody Radiation

The thermal radiation emitted by most objects, include stars, is similar to blackbody
Blackbody Radiation

![Blackbody Radiation Graph](image_url)
Thermal Radiation

The graph illustrates the intensity of radiation as a function of wavelength for different objects:

- **15,000 K star**: A very hot star emits most of its radiation at shorter wavelengths, primarily in the ultraviolet range.
- **the Sun (5,800 K)**: The Sun, being cooler than the 15,000 K star, emits more in the visible and infrared regions.
- **3,000 K star**: This cooler object emits most of its radiation in the infrared part of the spectrum.
- **310 K human**: At a temperature similar to room temperature, the human body emits most of its radiation in the infrared region.

The graph shows the distribution of intensity across the electromagnetic spectrum, with the x-axis representing wavelength in nanometers (nm) and the y-axis representing intensity in a relative scale.
Thought Question:

Which star is hotter?

the blue star

the red star
Thought Question:

Which star is hotter?

The blue star

The red star
A lump of Metal is heated to a high temperature. Another lump of Metal that is twice as large is heated to a lower temperature. Which lump of material appears bluer?

A) The cooler lump appears bluer.
B) The hotter lump appears bluer.
C) Both lumps look the same color.
D) Cannot tell which lump looks bluer.
A lump of Metal is heated to a high temperature. Another lump of Metal that is twice as large is heated to a lower temperature. Which lump of material appears bluer?

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**Participation Question**

- Take out a piece of paper, write your name and **Rocket ID**, and the answer(s) to this question:

- The _____________ (temperature) an object, the __________ its color.

- **Don’t forget to turn it in at the end of class in the back of the classroom on your way out for your participation credit!!!**
At relatively low temperatures, the poker emits only infrared light that we cannot see.

As it gets hotter, it begins to glow.

It gets brighter as it heats up (demonstrating Law 1)...

...and changes from red to white in color (demonstrating Law 2).
Reminders

- **Evening observing this week: last chance tonight.**

- **Mid-Term #2 Sep 30th, in class.**

- **HW #3 Due this Sunday.**

- **Turn in your participation sheets.**